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MAINTENANCE AND MANAGEMENT OF PROTECTION SYSTEMS

Working Group 34.06

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WG34-06 MAINTENANCE AND MANAGEMENT OF PROTECTION SYSTEMS

ACKNOWLEDGEMENT

This report has been prepared by CIGRE Study Committee 34 and is concerned with the maintenance and management of protection systems. Other groups are considering similar needs on other plant and equipment for electrical power systems.

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1. SCOPE OF THE WORK

The growing size and complexity of power systems generates increasing needs for maintenance and management efforts to optimise investment and renewal costs. On the other hand the rapid development of information technology can provide a new approach to reduce life cycle costs.

In that respect there is a need for international co-ordination in the field of design, construction and maintenance of power stations, substations and networks.

As one of the CIGRE's role is to encourage exchange of information between utilities and manufacturers, there is a challenge for obtaining better documentation systems and better engineering tools using the latest technology and means now available.

SC34 has considered these aspects from the point of view of protection and control systems and established WG 34-06 to investigate the following items:

1) identify the basic information needs for maintenance of protection and control installations,

2) review the present practices of utilities in this field,

3) review the present practices of manufacturers in this field,

4) identify the present difficulties and limitations of information systems for maintenance,

5) outline the prospective benefits from new information systems.

2. INTRODUCTION

To satisfy the scope of work it was essential to survey current worldwide practices among utilities and manufacturers. Before that, the group had to define its purpose and break this down into a list of objectives.

Thus the objective of maintenance and management of protection systems is:

"To maintain the most effective level of protection performance", Where "protection performance" is defined in terms of speed, selectivity, stability, sensitivity and reliability, and "effective level" is set by the utility appropriate to the system concerned and taking account of all influencing factors.

This objective can be divided into two parts:

1. Tasks to be performed.
2. Information requirements.

Tasks to be performed on protection systems (see Chapter 3 for definitions):

Maintenance.

Adjustment, repair, modification and/or investigation.

Refurbishment and/or replacement.

Measure cost/effectiveness of alternative methods.

Develop new or improved relays.

Application to the power system.

Performance analysis.

Information Requirements:

Monitor performance on fault

Provide operational and statistical data.

Provide data storage for subsequent analysis

Schedule work.

Establish the means to carry out the work.

Collect information from carrying out tasks.

Costs

Taking Account of:

Company policy.

Power system performance requirements.

Availability of skilled personnel.

Distance to travel to each substation.

Access to equipment (primary circuit in or out of service).

Method of data collection, storage and analysis.

Type(s) of equipment in service.

Manufacturer's recommendations.

Availability and quality of information.

Other (than protection) users of the information.

Availability of test equipment and connection to the protection.

Availability of cost information was judged to be increasingly important for the maintenance and management of protection systems and hence must be included in the surveys. Costs were broken down into the following components:

Initial Costs	Running Costs	General Costs
Approval of equipment	Maintenance	Overheads
Design (schemes)	Performance Analysis	Training
Purchase	Investigation	
Housing	Repairs	
Installation	Modifications	
Commissioning	Refurbishments	

Whilst referring wherever possible to the IEC Dictionary of Technical Terms, the group had to produce a complementary list of definitions which appears in Chapter 3 of this report. These definitions assisted the group in its work and will be of help to those who read this report.

Surveys were made of utilities and manufacturers and produced good returns, 45 utilities and 22 manufacturers responding. The 45 utilities were from the following areas:

27 - Western Europe
1 - Eastern Europe
1 - North America
3 - South America
2 - Africa
4 - Asia
7 - Australia/New Zealand

These responses reflect CIGRE membership and their numbers are a function of the organisation of the electricity supply industry in each particular country. Thus there were a large number from Western Europe, some countries submitted a single response (for a relatively large organisation) and others a number of responses (for relatively smaller organisations). In analysing the results, the utilities were divided into **large** (> 10 GW), **small** (< 2 GW) and **medium** (between 2 & 10 GW). The larger utilities operated higher voltage networks whereas some of the smaller ones operated only lower voltage networks. However all were admitted as being transmission networks.

The 22 manufacturers were from the following areas:

11 - Western Europe
2 - Eastern Europe
5 - North America
1 - South America
1 - Asia
2 - Australia

All were admitted as being separate manufacturing units with their own customers and practices, despite some belonging to larger worldwide groupings.

In addition the group also examined examples of the use of information technology in order to draw some of its conclusions.

Although the title of the working group appears to restrict its activities to protection systems, it was quickly realised that certain substation control elements must also be included for the results to be of wide benefit. Therefore automatic reclosing, synchronising and other similar equipment were embraced within the title "protection systems" in order to determine the needs for information gathering and analysis. Telecontrol of substations and system control were excluded.

The group became aware of some common concerns, particularly among utilities, all of which were associated with maintenance and management of protection systems. Thus for example, many are concerned to understand the most appropriate maintenance regime for their particular situation but feel that manufacturers could be more helpful in this regard. As power systems age, the question of refurbishment and replacement is assuming a higher profile with large levels of uncertainty as to the best solution, both technically and economically. Whilst there is also a desire to take advantage of new technology where appropriate, there are concerns over its long-term performance and even its lifetime in relation to the power system primary plant. The group has tried to address these concerns as best it can but feels that there is scope for more work in this area.

In considering how people were being employed to carry out various tasks, it was necessary to define their relative skill levels in order to obtain a reasonably uniform response. These are also given in Chapter 3 and are related to UK academic qualifications to assist people in judging their own particular situation.

3. DEFINITIONS*

(*) Reference to IEC41 (IEV448) (Sec) 88

Maintenance (of protection)
Determine by inspection and testing that the equipment is functioning correctly.

Repair (of protection)
Replacing a damaged part.

Modification (of protection)
A planned replacement of a part of avoid possible incorrect operation. (*)

Investigation (of protection)
Diagnosis after an incorrect operation of a protection system.(*)

Refurbishment (of protection)
Change(s) to a protection to improve its performance.

Replacement (of protection)
Replacement of a relay with another.

Setting Changes (of protection)
An approved change of device characteristic by an approved means. (Without wiring or component changes).

Adjustment (of protection)
An approved change of parameter to maintain the device characteristic within its design tolerance.

System Analysis (of protection)
Evaluation of protection system behaviour during a power system fault or other abnormal condition.

Relay Analysis
Evaluation of relay behaviour.

Information System
The organisation of gathering, storing and distribution of data.

Electrical Fitter (= ELECTRICIAN)

Qualifications : Trade certificate (UK: City & Guilds Craftsman Certificate).

Ability: Requires detailed instructions or close supervision to carry out work. Can perform relatively simple tasks unsupervised, possibly after directed training. Can work safely within a substation environment. Individuals who become supervisors of a group of craftsman, are able, through experience, to undertake more complex tasks to specific instructions.

Note:- Craftsmen who obtain higher trade certificates may be promoted up to technician grade.

- An electrical fitter will have left school at the age of 16.

Electrical/Electronic Technician

Qualifications: Technical certificate less than degree standard or a lower class of degree. Could be a member of an appropriate institution. (UK : HNC or HND, "Incorporated Engineer").

Ability: Can perform fairly complex tasks to an appropriate set of instructions and take decisions based on established criteria. Can, through use, become knowledgeable about particular equipment and hence be able to investigate problems. Will refer complex matters to the specialist.

Note: The technician could be a specialist in his own sphere or a member of a multi-discipline team (possibly with a higher qualification but only limited knowledge on the specialist subject).

A technician leaves college at the age of
18 - 20 : lower degree or
21 + : first class, honours degree.

<u>Electrical Engineer</u>

Qualification: To degree standard (ordinary or higher) and a chartered engineer (or qualifications leading towards chartered status). A member of the appropriate engineering institution. (UK: CEng, MIEE, BSc or BA or MEng or MSc).

Ability: Can undertake any kind of work without supervision and with only minimal instructions, can determine appropriate course of action, determine its effects and consequences, perform calculations of equipment reaction to stimuli and declare equipment fit for service on his/her own volition (i.e. without recourse to further advice other than from another specialist).

Note: An engineer has a university diploma or equivalent such as:

- CEng: Chartered Engineer (university + experience)
- MIEE: Member of the Institution of Electrical Engineers (one of the following + experience)
- BSc: Bachelor of Science (3 yr)
- BA: Bachelor of Arts (3 yr Oxford, Cambridge)
- MEng: Master of Engineering (4 or 5 yr)
- MSc: Master of Science (4 or 5 yr)

Abbreviations

U'Q = Utilities' Questionnaire

M'Q = Manufactures' Questionnaire

IS = Information System

4. CURRENT PRACTICES, PROBLEMS AND TRENDS

4.1 Introduction

4.1.1 Structure of the questionnaires

The scope of chapter 4 is to give a picture of the complex structure of matters related to maintenance and management of protection systems. The items making up this complexity are listed in Chapter 2 where the objectives of maintenance are stated. The result of the Utilities Questionnaire (U'Q) and the Manufacturer's Questionnaire (M'Q) are the main components giving a statistical base to the report.

The U'Q is structured into eleven sections as follows.

1. <u>Organisation</u> of the utilities includes general information on their size, use of technology and laboratory capabilities.

2. <u>Performance assessment</u> questions how utilities monitor the performance of their protection systems. An annex to this section provided detail on the logical and analogue parameters recorded.

3. <u>Philosophy</u> is the set of principles followed by the utilities in matters of modification, replacement and maintenance.

4. <u>Costs</u> asks questions on how costs are taken into account and in what detail.

5. <u>Information</u> is related to the gathering and storing of information on the devices both from manufacturers and in house, and its relative importance.

6. <u>Responsibilities</u> gathers information on the role of the Protection Department at its relationship with Telecommunication and Suppliers.

7. <u>Maintenance</u> concerns the procedures, frequency and protections maintained.

8. <u>Spares</u> concerns the organization of spares and repairs.

9. <u>Personnel</u> concerns the numbers of people and their relative skill levels.

10. <u>Life cycle costs</u> determines to what extent utilities collect this data and their expectations for reduction.

11. Subtransmission grid is a complementary section, to find out the differences between practices on this grid and the main transmission network.

In each of these sections questions were grouped into "subjects" and oriented towards three aspects:

- current practices for the major part of the grid,
- problems and trends (meant as expectations for the near future in view of the changes in technology, etc).
- future possibilities

The M'Q is structured into 5 sections as follows:

1. Identification (of the manufacturer).
2. Development (of protection) concerning the utilities' involvement in this field.
3. Maintenance concerning the role played by the manufacturers in providing information, assistance and servicing.
4. Spare parts concerning the manufacturers' policies in this matter.
5. Information concerning the quality, quantity and frequency of the exchange of knowledge to and from the utilities.

The two questionnaires resulted in more than 700 entries, therefore, it would have been difficult to present the raw data as received. For this reason appendices "A" and "B" provide a report on the questionnaires in the form of bar charts.

The aim of the WG was to analyse the questionnaires in detail, synthesize the answers, give an overview of current practices and trends and, where possible and meaningful, to correlate between different sections. In this respect correlation and comparison between the points of view of utilities and manufacturers are considered of particular interest.

The importance given by the respondents to each question can be checked directly by reference to appendices A and B.

Where appropriate evaluation of the answers takes into account the following

- Voltage levels of the grids;
- Redundancy in protection systems;
- Sizes of the utilities;
- Technologies adopted;
- Correlations with other parts of the questionnaire.

4.1.2 Comments on the organisation of the utilities.

This paragraph gathers general information about the utilities and should be read in conjunction with Chapter 2, and section 1 of Appendix "A".
The survey was concerned with Transmission but voltage levels as low as 90 kV were admitted on the grounds that they were operated as transmission systems. They were graded into Transmission, Subtransmission and others as in FIG. 1.

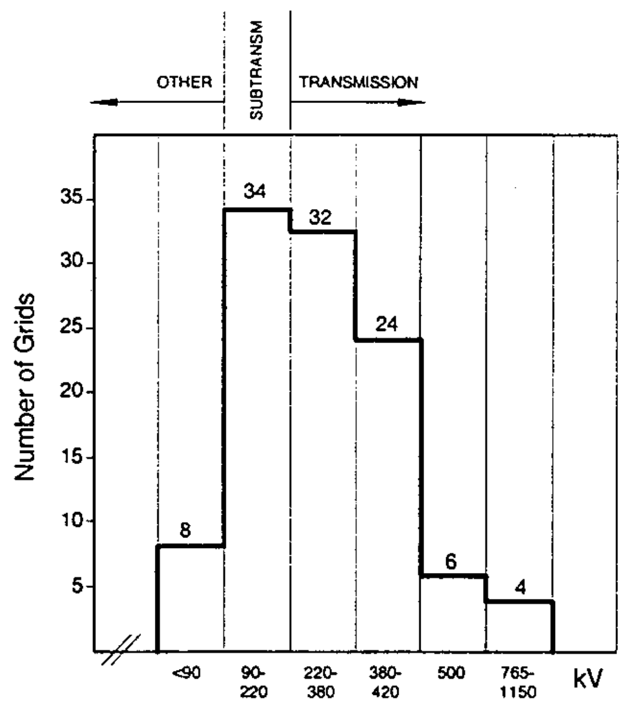


Fig. 1 Distribution of Voltage Levels

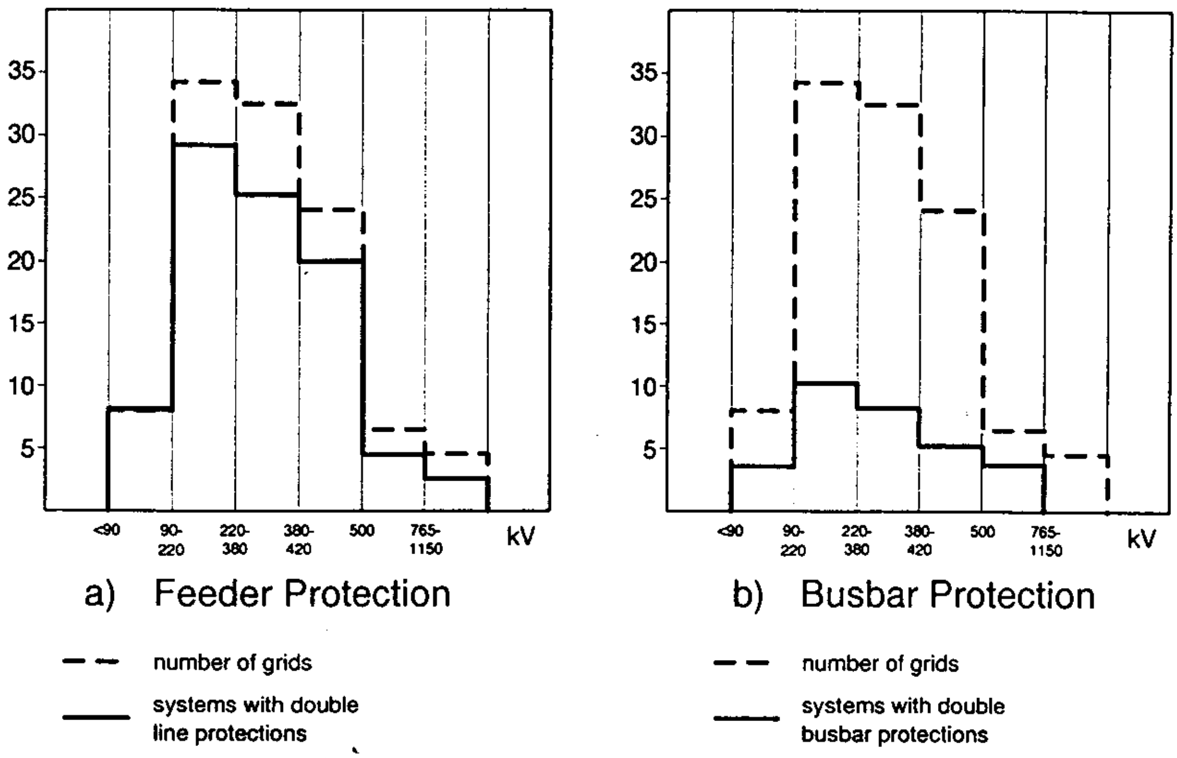


Fig. 2 Redundancy of Protection Systems

FIGs 2a and 2b show the redundancy of feeder protections and busbar protection against the distribution of the voltage levels of the grids.

4.1.3 Comments on the technologies.

Table 1 shows present and future use of the technology in the most common applications (feeders, busbars and transformers)

Application	Feeders		Busbars		Transformers	
TIME	PRESENT	FUTURE	PRESENT	FUTURE	PRESENT	FUTURE
NUMBER OF RESPONDENTS / TECHNOLOGY	44	39	43	39	44	40
Electromechanical Only	16%	-	30%	13%	25%	7%
Static Only	23%	13%	43%	28%	20%	15%
Digital Only	-	45%	2%	31%	-	37%
Electromechanical + Static	36%	3%	21%	8%	43%	13%
Static + Digital	7%	36%	2%	20%	7%	22%
Electromechanical + Digital	2%	3%	-	-	-	3%
Electromechanical + Static + Digital	16%	-	2%	-	5%	3%

Table 1 Technologies Adopted in Protection Systems (Present and Future)

With reference to feeder protections, for example, the table shows that present status is still characterized by:

- strong influence of electromechanical technology (alone and with static),
- maturity of the static technology.
- absence of wide experiences on digital technology,

Whereas the trend is towards:

- absence of electromechanical technology (which could indicate a need of retrofitting),
- decline of static technology,
- increasing use of digital technology.

The feeder protection figures also show that in future, static relays (alone 13% or with digital relays 36%) will reach similar percentages as electromechanical have now (alone 16%

or with static relays 36%). It is also evident that the hybrid situation (16% for electromechanical + static + digital) will disappear. The percentages are more diverse for busbars and transformers but there is no doubt about the growing importance of digital technology (31% and 37%)

4.1.4 **Comments on utilities' test capabilities.**

Nearly all utilities (96%) have test laboratories giving them test capabilities which are closely correlated to the autonomy of the users in matter of maintenance. Most laboratories are sufficiently well equipped to perform tests, ranging from type testing (65%) to repair (79%). Nearly all utilities (98%) can investigate failures of protections in their laboratories.

4.2 Performance assessment

4.2.1 **Analysis criteria.**

Section 2 of U'Q is devoted to survey the practices and limits of performance control of the protection system carried out by the utilities. This part was structured as follows:

Subject "a" titled "data collection" related to the data collected from the network itself and from the laboratory activities

Subject "b" titled "Analysis of HV faults" related to the statistics and fault analysis performed on the data collected.

To complement the two subjects, an investigation was made into the information collected from the field by means of analogue and event recorders.

4.2.2 **Comments on data collection**

Appendix "A", section 2, summarizes the positive answers of the utilities to subject "a" of the questionnaire,

The highest number of YES answers is given to the first subsection regarding the systematic collection of data from the field about the H.V. fault itself. Most utilities (93% mean value) keep records on the primary faults, the exceptions coming from small power systems. Similarly, they keep records on the behaviour of the protection during HV faults (88% mean value). It is worthwhile noting that only 2 utilities out of 45 do not use disturbance recorders.

The majority of utilities (93%) continue to record indications from relays. Does this show that the disturbance and event recorders do not retain enough information? Will this recording of relay indications continue with the trend towards digital technology and reduced manning levels?

The third subsection still shows high levels of recording (87% mean value for kind of failure and 67% mean value for kind of repair) associated with relay maintenance or post incident testing. This indicates the relative importance that utilities place on collecting these data, some of which is supplied by manufacturers.

However the fourth subsection shows a low interest in keeping records on unavailability (36% mean value). Could this be related to the probable difficulties in evaluating it? Interest may be heightened and difficulties may be reduced in the case of digital relays due to their self-checking capabilities.

4.2.3 **Comments on analysis of H.V. fault**

Appendix "A" section 2, summarizes the positive answers of the utilities to subject "b" of the questionnaire.

It should be noted that the maximum of yes answers is never higher than 43. This is probably because 2 utilities out of 45 do not use event and analog recorders and therefore find it difficult to produce statistics.

Regarding the release of the statistics collected by the utilities, only a small proportion of the utilities release these information outside their organization even though more than half (56%) could do so on request. In particular very few utilities (22%) release data regularly to the manufacturers. This is confirmed by the manufacturers' answers and seems to be consistent with the opinion of most utilities. According to the utilities it is not so important to feed back to manufacturers in order to get their cooperation.

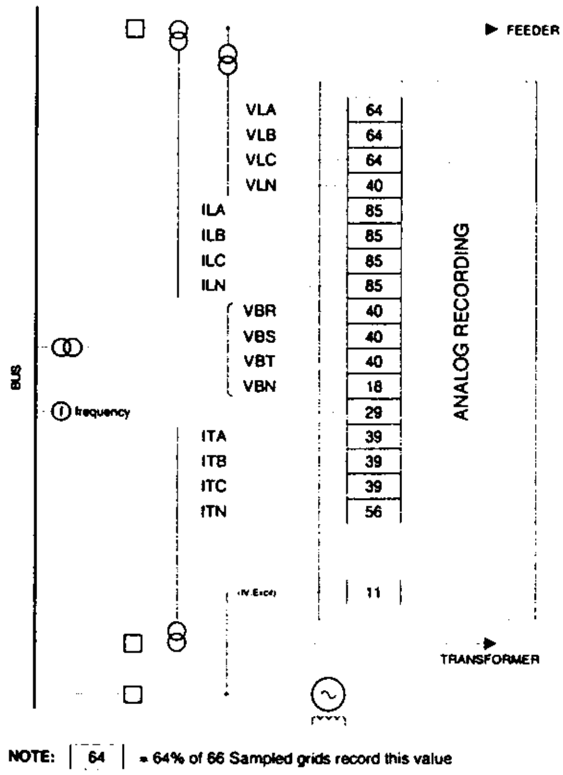


Fig. 3a Analog Recording in Transmission Networks

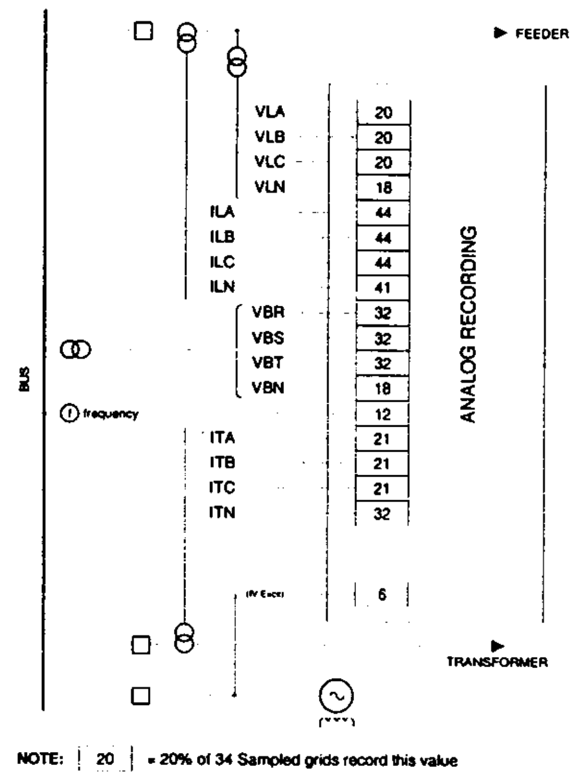


Fig. 3b Analog Recording in Subtransmission Networks

4.2.4 Information collected by means of analogue and event recorders.

The answers given on this subject were analysed in relation to the kind of grid (transmission or subtransmission) as previously defined. Figs 3 a) and b) refer to the analog recordings and summarize the positive answers as percentages of the number of the respective grids.

Comparing the two figures it is evident that transmission grids are monitored more comprehensively than the subtransmission grids. In the former for example, 85% of grids have their line currents recorded which should be enough to have significant information for HV fault analysis and in particular to evaluate clearance times.

Voltages are not frequently monitored at both bus and line terminals. Therefore summating the percentages reported in fig 3a show that voltages are monitored at about 100% in transmission grids and about 50% in subtransmission grids.

Figs 4a and 4b show the status of the event recording, divided as for Fig 3.

Trip commands of line protection are the most frequently monitored events; this is consistent with the attention paid in the statistics to the behaviour of protections.

Paper is still the most common method of data collection (86%), followed by electronic files (30%). Electronic mail (of electronic files or paper) from the field to remote centres is used in 47% of cases.

Recorders do not appear to be frequently synchronized across the network (18%), while they are more frequently synchronized within the substation (30%).

4.3 Philosophy

This refers to section 3 of Appendix "A".

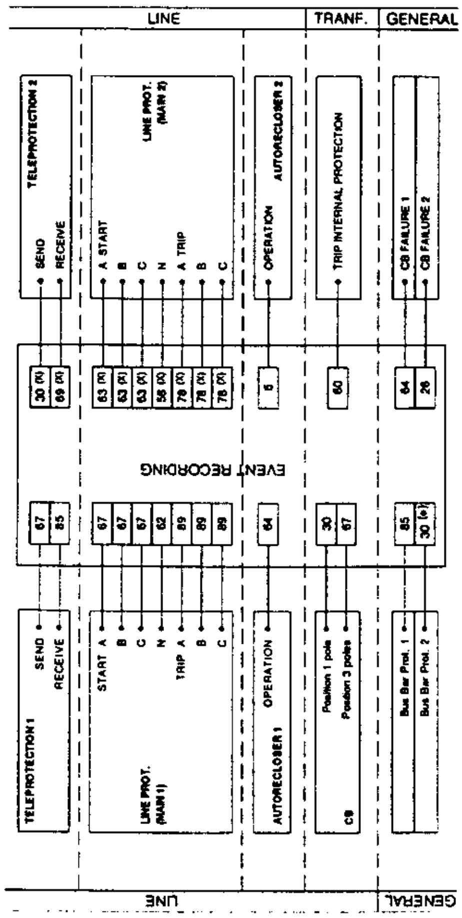


Fig. 4a **Event Recording in Transmission Networks**

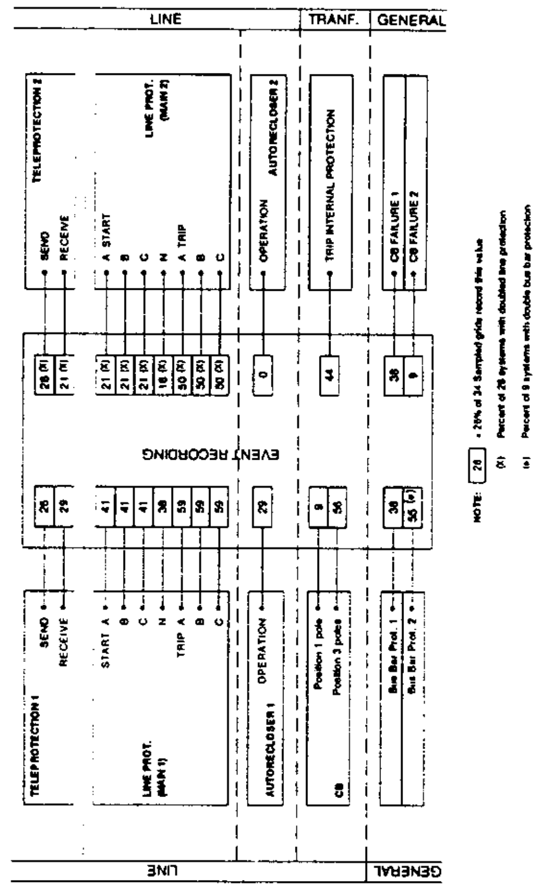


Fig. 4b **Event recording in subtransmission networks**

4.3.1 Modification of equipment.

Most of the utilities (80%) systematically modify all relays of the same type after incorrect operation discovered by the utility or its laboratory. A similar number (80%) of utilities modify relays following advice from the suppliers. However, the implementation of this advice depends on the size of the utility. A more detailed analysis (see Table 2) shows that small utilities get less information from the supplier on regular basis (20%) or on request (40%) compared with large utilities where corresponding figures are 33% and 67% respectively. If they receive it, small utilities tend to follow the advice (80%), whereas larger utilities are less likely (67%).

More than half of all utilities state they do not receive regular information about modifications and incorrect operation from the suppliers. This is consistent with the fact that 50% of the manufacturers say they supply utilities with systematic information about every type of modification to a relay. This may be due to the utilities themselves not providing regular information about their relay problems. This is a very delicate point as it is based on mutual confidence of giving and taking.

Less than half of utilities (36 %) state they carry out refurbishment to cope with new objectives and new protection principles. Here again there is a different approach depending on the size of the company whereby 56% of large utilities upgrade their installations, whereas only 31% of the smaller utilities do so.

4.3.2 Replacement of equipment.

The pattern emerging from analysis of the responses on refurbishment is more strongly stated for replacement. The larger the utility, the more they replace protection equipment to cope

SIZE OF UTILITY	LARGE	MEDIUM	SMALL	TOTAL
RESPONSES	9	26	10	45
Systematic modification				
after incorrect operation	78%	81%	80%	80%
on advice from supplier	67%	85%	80%	80%
advice on regular basis	33%	35%	20%	31%
advice on request	67%	46%	40%	49%
Refurbishment only to cope with new goals	56%	27%	40%	36%

Table 2 Modification and Refurbishment

with new protection principles or characteristics (100% for large 70% for small). The figures have to be considered with care, as there is a big difference between "replacing in a specific case" and "systematically replacing a type of relay all over the grid".

Apparently, large utilities have more confidence in modifying their relays as only 22% of them find it necessary to replace protection equipment after incorrect operation, against 50% of the small utilities.

Perhaps surprisingly, only half of the utilities replace their equipment when spares are no longer available. However this does not include the possibility that utilities may replace some relays in order to get spares. It is also possible that utilities postpone the replacement of their protections until a failure is recognised.

Most of the utilities (84%) replace relays when the tripping time or sensitivity gets beyond a certain limit. It follows that utilities set their limits but they must be within the design parameters stated by the manufacturer.

Table 3 shows in detail the results reported above

4.3.3 Providing for maintenance in the design

a) Protection cubicles.

In 22% of utilities protection systems are not designed such that maintenance tests can be easily executed. In 33% of utilities wires have to be disconnected or links removed in order to perform normal maintenance tests.

SIZE OF UTILITY	LARGE	MEDIUM	SMALL	TOTAL
RESPONSES	9	26	10	45
To cope with new protection principles or characteristics	100%	77%	70%	80%
When technical degridation is observed	78%	88%	80%	84%
When problems are investigated repeatedly during maintenance	78%	81%	60%	76%
When spares are no longer available	78%	35%	60%	49%
When the utility often states incorrect operation	22%	42%	50%	40%

Table 3 Reasons for Replacement of Equipment

These figures concern the major part of their grids and do not always reflect the situation on new equipment.

Larger utilities more often have a standard design of protection cubicles incorporating test facilities (78%) than smaller utilities (about 50%).

Many utilities (76%) can easily maintain protections with the circuit on load and 53% of them effectively do so (see 4.7.1).

b) Test connectors.

It is more common to have test connectors for individual relays (73%) than for complete protection systems (60%).

A little more than half of the utilities (58%) use standardised test connectors which are independent of the supplier of the relays. This is more common for the large utilities (78%) than for the medium and small utilities (about 50%).

Could this indicate that there is no real need for test connectors which are part of in the relay itself, for injection of currents and voltages? Therefore utilities having standardised test connectors should need less time to perform routine checks on their protections and there is less chance of incorrect test connections.

Almost 70% of utilities which are able to maintain their protection with the circuit on load use the test connector to isolate the trip output.

Table 4 shows in detail the results reported above.

SIZE OF UTILITY	LARGE	MEDIUM	SMALL	TOTAL
RESPONSES	9	26	10	45
TEST CONNECTORS:				
Are standardised and independent of the supplier of the relays	78%	54%	50%	58%
Are used for:				
each protection relay	67%	73%	80%	73%
each protection system	67%	62%	50%	60%
automatic control equipment	33%	15%	30%	22%
MAINTENANCE TESTS:				
can be easily executed	78%	77%	80%	78%
require disconnection of wiring	33%	31%	40%	33%
are possible with circuit on load	89%	73%	70%	76%
HOUSING:				
A standard design of protection cubicle incorporating test facilities is used.	78%	54%	50%	58%

Table 4 Providing for Maintenance in the Design

4.3.4 Records of equipment installed (type, behaviour).

Most utilities already keep records of all necessary information about their relays and their associated grid. In order to see a long term evolution and to be able to take conclusions out of this huge amount of data it is almost essential that this information is stored in a computer data base. The more data to store, the more this is true. As could be expected, larger utilities are more willing to use computers for management, now or within 5 years from now, than smaller utilities depending on the kind of information as shown in Table 5.

It is apparent that large utilities intend to keep operation's reports on computer to a greater extent than maintenance reports. This could be due to the relative importance of the information, the volume of data to be managed and analysed and the ease or difficulty of collecting the data.

4.3.5 Calculation of settings.

Five years from now, 80 % of all utilities intend to use computers to calculate the primary, as well as the secondary settings of the relays. With the introduction of digital relays the secondary setting can be part of the relay software or an external setting software programme. Will the manufacturers present this information as primary or secondary values or both? It is likely that the user will require both.

SIZE OF UTILITY	LARGE	MEDIUM	SMALL	TOTAL
RESPONSES	9	26	10	45
Main protection relays data	100%	81%	70%	82%
Operation reports	100%	58%	40%	62%
Maintenance reports	67%	50%	60%	56%

Table 5 Information on Computer (now or within 5 years)

The fact that 80% of utilities intend to use computers to calculate primary settings is perhaps surprising. Possibly some of the replies related to the calculation of a simplified part of the network and in addition some utilities may be considering separate calculation of the relay secondary values rather than automatically calculating them from the same network program.

4.4 Costs and life cycle costs

This refers to sections 4 and 10 of Appendix "A".

4.4.1 Records of cost

A large proportion of utilities (73%) keep costs of new protection relays and consider these to be fairly important, whereas the cost of introducing new relays, for example, the cost of type testing, training, etc., is kept by far fewer utilities (16%), and these costs are considered less important taking into account the low number of responses. Perhaps one reason for the difference is that information for relays is readily available whereas other costs, particularly utilities in-house costs are not so widely known.

The number of utilities keeping costs of doing work for protection refurbishment or extensions to the grid system is well below half (36% and 38% respectively). The importance of these costs is viewed to be similar to the importance of the cost of protection relays. This could be indicating an intention by more utilities to keep records of the costs of these important activities in the future. A somewhat smaller proportion (16%) of utilities indicated that lifetime management costs were kept with a medium importance factor associated with this particular cost. The reason for this lack of information is most probably the unavailability within utilities of lifetime cost records.

Almost half (49%) of utilities responding said they keep costs of new protection cubicles. A high proportion of respondents thought that these costs were in the range of important to essential. It is likely that complete cubicle costs are available to some utilities and thus the data is kept. The cost of complete cubicles will represent a higher proportion of installation cost and naturally, therefore, this component of cost features higher up the league table of importance.

When broken down into individual costs, "purchase of relays and cubicles", and "site installation" were kept by nearly half (47%) of utilities and rated moderately important. Cost relating to "design of schemes"," tests at suppliers and on site", and "buildings to house protection equipment" were kept less frequently (38% of utilities) and rated less importantly. In house overheads for construction activity featured the lowest response, only 11% of utilities keep these costs, and they received the lowest interest.

Nearly half the utilities (49%) conceded that they keep records of man-hours performed and costs of maintenance. When analysed against the number of responses, costs associated with total man-hours per substation featured more significantly. This indicates that the macro scene is viewed more importantly than the micro one.

On the subject of spares, well under half (40%) of utilities keep records of purchase of spares and substantially less (16%) monitor the turnover of spares. This should perhaps be related to the fact that 80 to 87% of utilities keep their own spare circuit cards or relays respectively.

The cost of running a protection department was admitted by 18 utilities (40%) although the cost was ranked as very important.

As a conclusion it is assumed that the availability of cost data is probably a relevant factor when utilities make the decision to keep records of costs for the management of protection.

4.4.2 Life Cycle costs

With regard to life cycle costs, 50% of respondents intend to reduce life cycle costs of protection in the near future. Somewhat more (63%) intend to control life cycle costs in order to make better decisions in matter of protection. This indicates that life cycle costs will in future be an important element in the management of protection. At the moment few utilities apparently keep lifetime management costs or consider it to be highly important.

Respondents were asked to indicate out of a list of 8 identified areas, the top three in which they wanted to gain in reducing life cycle costs.

Fig.5 indicates the distribution of interest. This shows that a reduction in "maintenance time" is a key objective with "self check" featuring highly as another maintenance reducing feature. The "initial cost of relays", "installation and commissioning" and "training" all received an equal share of vote. Lifetime featured lowest. This is the conclusion today with the lifetime of relays being at least 20 years, however if the lifetime of digital relays is much shorter then the life cycle costs will be affected.

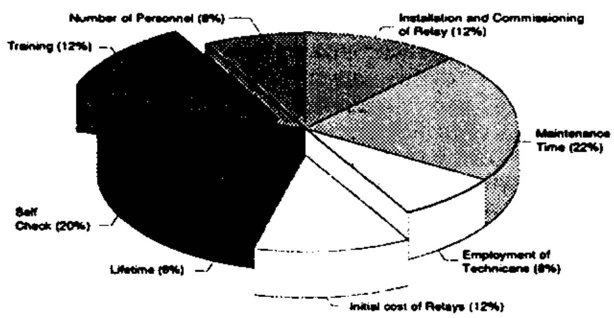


Fig. 5 How Utilities Want Life Cycle Cost Reductions to Materialise

There is low interest in the gain to life cycle costs from a change in the number of personnel. At first sight this seems to be at variance with the expectation to gain from improvement in maintenance time. Does this indicate that existing maintenance personnel undertake different work?

Nearly two thirds (63%) of utilities expect the introduction of digital technology to reduce life cycle costs. Turning the analysis around there are at least a sizeable proportion (37%) however who are at least sceptical about the benefits that digital relays will afford.

The interest expressed by utilities in reducing maintenance costs may be compared with the manufacturers replies on this related subject. Just over half (55%) of manufacturers, who give a recommended maintenance frequency, recommend also a different (presumably a longer) time interval for relays with self checking, a feature high on utilities aspirations for life cycle costs reductions.

It might be expected that in future utilities will request life cycle data such as probability of failure, lifetime, etc from manufacturers in their commitment to control and drive down life time costs. According to the manufacturers this data is only provided if it is requested by a utility and then only 64% of manufacturers will supply such data. Why are manufacturers reluctant to publish this valued data? Are they concerned that the data will be incorrectly interpreted or used? Does this indicate that there is a need to have a standard requirement for the way in which reliability data is presented to encourage manufacturers to be open about their products lifetime performance?

4.5 Information

This refers to Section 5 of Appendix "A" and Section 5 of Appendix "B".

The utilities require various kinds of information in order to optimise the management of their protection systems. This information is covered in the following clauses:

4.5.1 Basic information documents

The application guide together with a description of working principles enables selection by utilities of the type of protection which is best suited to the grid to be protected. These are required by over 93% of utilities in both cases and are supplied by almost all manufacturers, at least on request.

The commissioning and maintenance manuals together with the external diagram of connection for the relay are required by the utilities to install and operate the equipment within the network. The utilities requirements are very high (87 to 98%). This coincided with the manufacturers supply (100%) at least on request. As a supplement to the maintenance manual, only 40% of the surveyed manufacturers supply a "fault tracing chart".

Among the surveyed utilities, 76% require that a method for setting the protection systems be supplied by the manufacturer. This is mostly supplied by the manufacturers in the application guide.

Nearly 75% of utilities would like to have the protection system test reports available. Nearly all manufacturers provide such information, but on request.

4.5.2 Technical documents for maintenance engineers

Approximately 80% of the surveyed utilities keep a list all devices within each protection. Nearly 70% of the utilities keep a list of cards within each protection and almost all manufacturers are willing to hand over this document on request. Nearly the same situation is noticed for the internal connection diagram. It is possible that certain manufacturers are a little more reluctant at supplying information that they consider proprietary. However 77% of manufacturers claim to provide a list of all components. It may be worthwhile to propose to manufacturers a standard list of minimum basic and technical documents to be provided automatically to the users.

4.5.3 Software-oriented documents

The "flowchart of software", a document reserved for software specialists, is required by nearly 60% of the utilities and, this is well matched by manufacturers since, 68% of those surveyed are willing to make it available on request.

The "source of software", which is a more specific document, is required by approximately 30% of the utilities. On the other hand, only 10% of the manufacturers are ready to supply this information on request. As this document is a proprietary one and is not specifically required for the operation of a protection system this does not seem to be a major problem. Perhaps, it is only necessary for the manufacturer to specify the elementary functions performed by the software and to inform the users of any functional changes. The monitoring of software version for digital equipment is an important problem not specifically addressed by the questionnaire.

4.5.4 In-house information required for monitoring of equipment in the network

Nearly all utilities keep information about the type, mark, age, rating, range, etc., of their protection relays. This type of information is easy to manage; 40% of utilities already store these data on a computerised system and more than 80% of them will do so in the next five years.

Substantially less utilities keep records of the historical overview of each protection relay. The management of this evolving document is obviously more burdensome since it has to be updated each time a significant event affects the equipment. However some 45% of utilities are considering managing this information on a computerized system in the next five years.

Most utilities keep record of maintenance reports. This is currently kept as paper records by 80% of utilities. Nearly 60% of utilities say they will be keeping these records on computer within the next five years. Perhaps these reports will be generated automatically by a computerized system whenever the use of portable automatic test systems (computer-controlled) are used on site and their use becomes more wide spread.

Operation reports which describe the correct or incorrect behaviour of protection systems in the presence of a fault, are kept by the majority of utilities. These reports often reveal if a problem has occurred in the protection system during operation. If a malfunction is detected, a maintenance action may be initiated to check the equipment. Nearly 60% of utilities keep this information on paper now with just over 60% of utilities having this information on computer within the next five years.

With digital protection systems the possibility exists to generate such reports automatically by remote interrogation of the protection systems via a computer. An expert system analysing this information or the information supplied by event recorders may infer whether a protection system has correctly or incorrectly reacted in the presence of a fault. The behaviour study for each protection system in the network could thus be significantly facilitated.

The study of protection systems behaviour in the network can assist with the optimisation of maintenance and give important indicators of application and performance to studies of reliability, dependability, security etc.

Only 41% of manufacturers reported receiving statistical surveys from utilities on performance during HV system faults and 55% of manufacturers receive statistics on failures detected during maintenance. However as more than 80% of the manufacturers say they give feedback to utilities of reports of incorrect operations of a type of relay one can assume their information is not complete.

From the utility side, only 22% say they provide the manufacturers with the incident analyses and the performance evaluations of the protection systems. The manufacturers could use this information to improve the reliability and features of their product and therefore a better collaboration between utilities and manufacturers would be worthwhile.

Records of setting calculation are kept by the majority of utilities and these are mostly kept on paper files at present. Some 60% of utilities say they will have this information on computer within 5 years.

The grid characteristics (R, L, X) of lines, cables, transformers, etc, are collected in local files by more than 70% of utilities; less than 30% of them are currently kept in central files.

To optimally manage a network of protection systems, most of the information mentioned above is required. However, to be useable, this information must be accessible and of sufficient quality. Quality is often difficult to obtain, since the information must be both reliable and comprehensive.

For example, consider a statistical survey on faulty relays. This information collected relative to each relay failure must be precise and comprehensive. The quality of the information collected could be significantly improved by setting up a well designed failure report form. Moreover, all relay failures must be taken into account. This is the price to be paid to achieve high quality information.

The accessibility of such information implies that transmission utilities are generally well organised.

When such information is on paper, copies are often required to transmit it to the various interested parties (regional department, central office, manufacturer, etc). The use of a computerised system and electronic mail would improve circulation of information while facilitating access to it.

4.6 Responsibilities

This refers to section 6 of Appendix "A".

4.6.1 Protection responsibilities

The existence of a Protection Department is a general practice (96%). This Department in the central office, is in charge of establishing the company protection policy and activities in relation to new installations such as introducing new techniques, approving the use of specific relays and choosing relays for specific applications.

Setting are also its responsibility except in 2 utilities where it is carried out by Regional Staff. In 2 others large utilities the latter practice is applied only for lower voltages such as 130 kV.

Maintenance is done by Central Department or Regional staff depending on the size and structure of the company. In the cases in which maintenance is decentralized, the planning of this maintenance tends to be decentralized also.

Maintenance and commissioning procedures are mostly the responsibility of the Central Department (over 80%). These procedures are mainly made in coordination with maintenance crew (80%). However, coordination with the supplier is not so common (53%).

4.6.2 Teleprotection responsibilities

The responsibility of teleprotection depends on the structure of the company. This responsibility belongs most commonly to the Telecommunication Service. The Protection Service tends to be involved more in commissioning than in maintenance. Communication links used by protection are mainly the responsibility of the Telecommunication Service.

In nearly all the cases there exists a decentralized close relationship between Protection and Telecommunication Services which is considered essential. Only 2 cases are reported in which this relationship does not exist.

4.6.3 Supplier involvement

Mutual confidence between utility and supplier is considered essential by utilities. How to get that confidence however is not clear. Regular meetings, which seems to be the usual way for communicating with manufacturers, are considered slightly less important although 75% of manufacturers say they have regular meetings with the utilities. Utilities seem to consider that it is more important to get information from the supplier than to provide feedback to the supplier. This fact seems contradictory as obviously manufacturers needs information from utilities in order to understand the behaviour of their relays.

Regarding feedback from suppliers of relay incorrect operations, it is interesting to note that although most of the utilities (80%) consider it an essential aspect, 5 utilities consider it as not important at all. In order to improve the relationship between the manufacturer and the utility it would seem that regular feedback to the manufacturers of the relay behaviour is a key point.

Regarding training for maintenance crews most manufacturers (85%) offer training services. The requirements for supplier involvement in the utilities personnel training however is moderate and even 10% of the utilities consider it as not important at all.

Utilities consider a good response to solve problems as they occur as more important than quick assistance on site when major incidents occur. This means that utilities require good remote support from the manufacturers rather than a local response.

Regarding technical support utilities consider that it is very important that suppliers ensure that knowledge is maintained for more than 15 years.

4.7 Maintenance and spares

This refers to sections 7 and 8 of Appendix "A" and section 3 of Appendix "B".

4.7.1 Regular maintenance.

More than 70% of utilities have written test procedures for each type of protection relay and more than 90% have test forms to fill in. Utilities carry out maintenance with different degrees of regularity depending on the type of equipment involved. The highest priority is given to main protection (93%) and back-up protection (89%). Busbar protection, circuit breaker failure protection, voltage and frequency protection score around 80%. A lower priority (around 65%) is given to teleprotections and automatic switching equipment.

About 50% of the utilities do maintenance testing with the circuit on load.

Surprisingly as many 33% of the utilities carry out the same tests during regular maintenance as during commissioning although a reduced maintenance test might save them time. Perhaps they are testing the relay equipment with automatic test facilities in both cases.

No utility has an average maintenance test interval which is less than 1 year whereas 43% use a test interval of more than 2 years. Several of the utilities have made the remark that they have different intervals for different kinds of protection or grids.

All manufacturers give maintenance instructions for the relays and 50% include recommended test intervals.

About 75% of the manufacturers who give recommended test intervals also recommend different test intervals for different types of relay and over half recommend different intervals for relays with self checking.

More than 75% of the manufacturers recommend which test equipment to use and 36% also provide programs for automatic test equipment.

About 40% of the utilities intend to do maintenance less often on relays with self checking or automatic self testing than on those without. This means more than half of utilities do not expect that relays with self checking facilities will allow them to do maintenance less often. Most utilities do not differentiate between the maintenance requirements for systems with two main protections rather than one or with static versus electromechanical relays.

As for the next 5 to 10 years, about 45% of the utilities foresee the same maintenance interval and almost 50% of the utilities foresee maintenance less often based on experience, the tendency is to reduce maintenance rather than to increase it based on condition and experience.

A few utilities stated they intend to base the maintenance more on a detailed analysis of relay behaviour during power system faults rather than on regular maintenance intervals.

4.7.2 Investigation and repair

All utilities do a special test on a relay after an incorrect operation. Less than 10% of the utilities involve the suppliers for these tests. Most of the manufacturers return the same relay to the utility after repair if possible and provide the utility with a report of the failure and measures taken.

Almost 70% of the manufacturers recommend that utilities can repair relays themselves by replacing cards or plug-in modules but only one recommends replacing individual components.

Most utilities expect turn-around from the manufacturer when they return a faulty relay to be less than 6 months, but only 35% think this is satisfactory. 75% of the manufacturers say they have a target period within which they return or replace a faulty relay and nearly 80% claim to have a target of less than one month. Most (75%) claim to have a success rate of more than 80%. If these targets were met the utilities would be probably satisfied but remain sceptical.

4.7.3 Spares

All utilities have spare parts for relays in centralised or decentralised storage. About 85% of the utilities have spare relays or spare printed circuit cards and 50% have spare components. Only 15% of the utilities have repair kit for each type of relay. Only half of the manufacturers recommend which spare parts their customers should hold and 25% of the utilities keep the manufacturers' recommended levels of spares.

Manufacturers guarantee of spare parts availability and utilities expectations do not coincide as can be seen in Table 6 below.

Although utilities rate the importance of the supplier holding spare parts for more than 15 years as very important, only 20% expect that this will be achieved.

Regarding digital relays, manufacturers say they will support software programs for the same period of time as they will have spare parts available.

4.8 Personnel

The survey sought to establish the current position in utilities regarding their use of personnel to maintain and manage protection systems and to assess the likely impact of new technology. Thus numbers of people employed at various skill levels have been related to size of utility and complexity of task whereas deployment of personnel has been related to type of task. The actual responses of the utilities are shown in section 9 of Appendix "A" and subsequent analysis in Figures 6 to 10. Definitions of "fitter", "technician" and "engineer" are given in chapter 3.

4.8.2 Skill levels

All protections have basic characteristics of speed, sensitivity, reliability and security. However, as system demand increases, there is a need for higher transmission capacity and interconnection requiring higher voltage levels and increasingly

Period	Manufacturers Guarantee	Utilities Expectations
< 5 years	10%	0%
5-10 years	50%	35%
> 10 years	40%	65%

Table 6 Spare Parts Availability

sophisticated protection and control. Thus total numbers of people employed and their skill levels must have some relationship to the size and complexity of a transmission network and its demand.

Although the average numbers shown in Appendix A, item 9.8 virtually show a 1:1:1 relationship between fitters, technicians and engineers, in practice these figures vary widely among utilities. The four graphs in Figs 6-9 show how these numbers vary according to the size of each utility as measured by GW demand. The lines drawn through the points on each graph merely indicate the trends. Thus the ratio of fitters to engineers or technician to engineers vary from less than unity upto 5 or 6. The way in which a particular utility maintains and manages its protection, whatever the technological mix of equipment, will be a function of the numbers of different skilled staff available to it. The graphs do show however that there is considerable scope for change, depending on the objectives of the utility.

The tasks listed in 9.1 to 9.6 of the survey have been rated in terms of complexity, and the numbers of utilities employing fitters, technicians and engineers to carry them out has been plotted against them in Figure 10. This shows that technicians are widely employed across all tasks. Fitters tend to be employed mostly in the lower skilled tasks whereas the higher the skill the more engineers are employed. Large utilities tend to use, for lower tasks, less engineers and more technicians and fitters. There is no such difference between small and medium sized utilities.

Over half the utilities reported engineer recruitment difficulties, slightly less for technicians and just over a quarter for fitters. Against that almost a third report that they expect to employ more engineers due to the introduction of digital equipment, Cigré 34-06 Utilities Survey

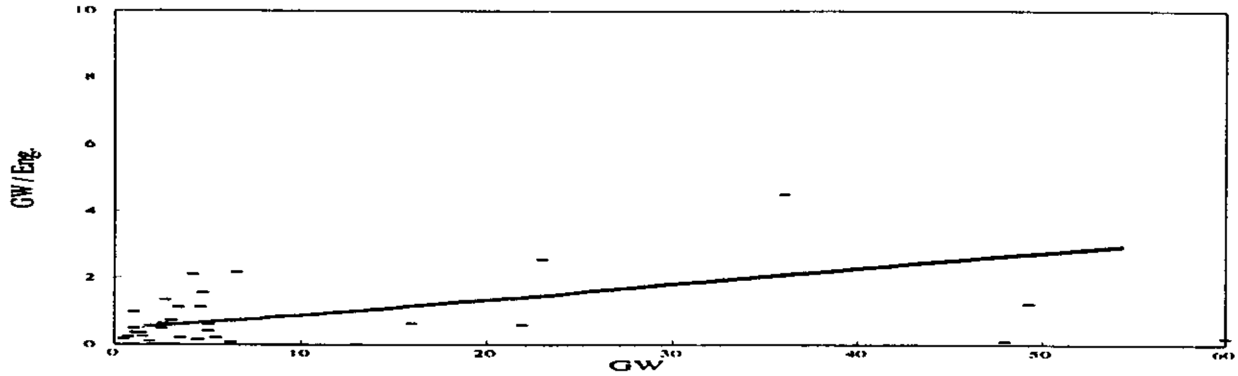


Fig. 6 Ratio of GW Demand per Engineer

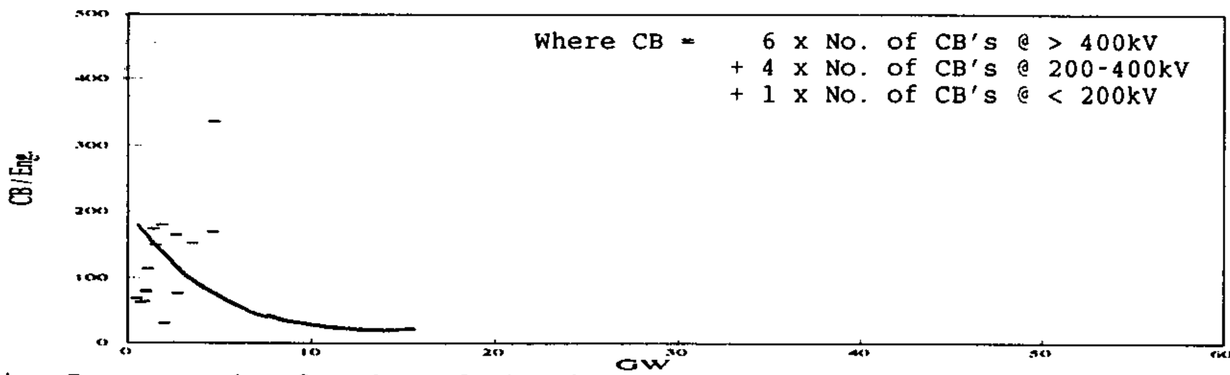


Fig. 7 Ratio of Number of Circuit Breakers per Engineer (weighted values)

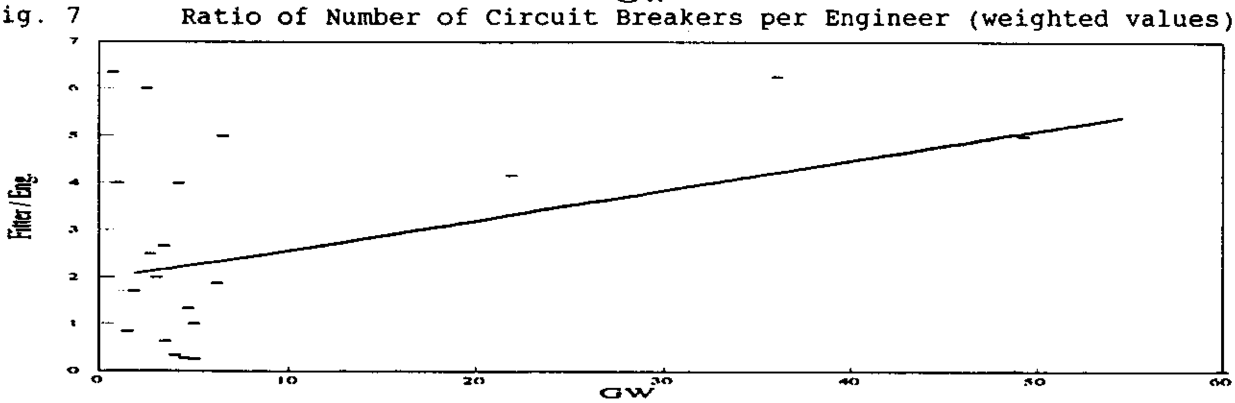


Fig. 8 Ratio of Fitters to Engineers

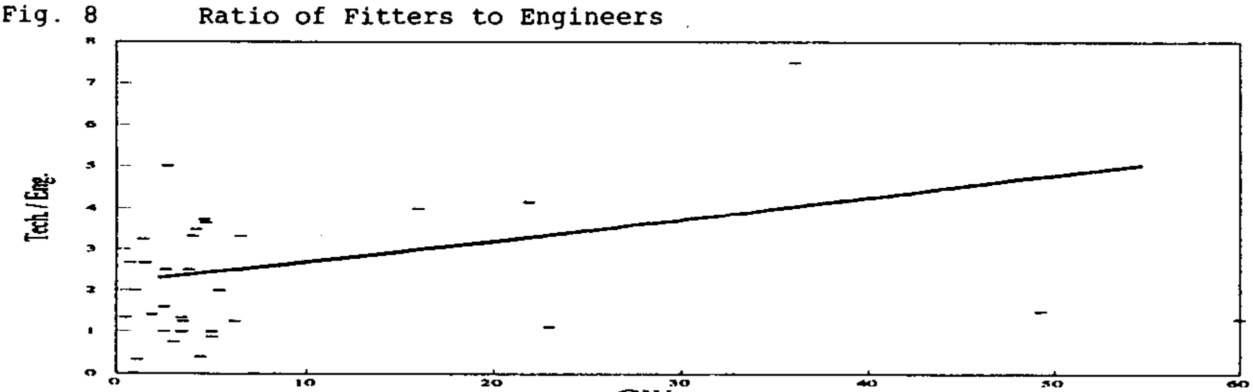


Fig. 9 Ratio of Technicians to Engineers

a quarter expect to employ more technicians. Only 7% expect to employ more fitters.

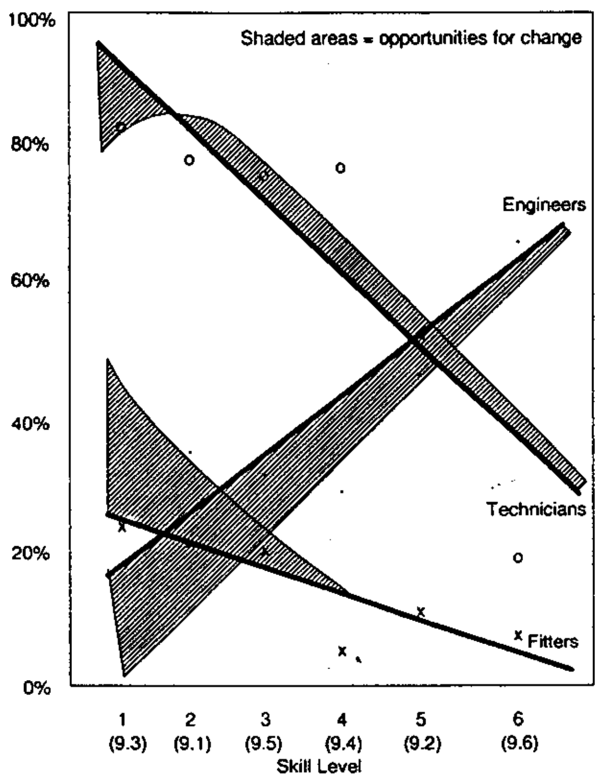


Fig. 10 Personnel - Skill Levels Number of Utilities Reporting Use of Fitters, Technicians & Engineers

A considerable amount of protection maintenance and management is carried out by central staff within utilities, even devolved work such as maintenance. The extent to which regional staff are employed depends on size of utilities and the skills available in the regions.

Very few utilities use contractors for maintenance but they are employed in training utility staff, especially for the introduction of new types of protection. Even in this category, three quarters of utilities do not use contractors but depends heavily upon their central staff.

4.8.3 Evolution of skills.

Although general trends can be observed, there is wide diversity reported by utilities in their employment of personnel, as shown in Figures 8 & 9. Therefore there appears to be room for improvement in some utilities taking account of their different situations and interpretation of the questions.

Whilst some utilities are successful in employing technicians or fitters for lower skilled work, others seem to depend heavily on engineers to carry out much of the work. The shaded areas of Figure 10 indicate where changes in skill level can be achieved. Knowing where such changes can be made as stated previously, will depend on the skills available within a particular utility. Gathering and analysing data on equipment performance (e.g. to determine the most appropriate maintenance philosophy) and task performance (to determine the best methods) will be additional factors. Successful use of lower skilled staff will depend on adequate training and good information flow to set down the tasks to be performed, including advice from equipment suppliers. Lifetime management features built into relay system design and use of automatic test equipment will also assist.

Whilst analysis of data will remain a relatively highly skilled task, data entry can be undertaken by less skilled staff provided the means of entry are appropriate to the task and skill level and the data input requirements are well defined.

Digital relays, controllers and test equipment have the inherent capacity to capture data. Transfer of this data to the point of analysis without the need to transcribe information will improve the utilities' ability to collect and analyse data and enable them to use less skilled staff to carry out some of the tasks.

The widespread difficulties in recruitment coupled with the perceived increasing needs of higher skilled staff due to use of digital equipment emphasises the need for improvements in utilisation of personnel as described above. This will require a range of training provisions.
Although relatively little use is made of contractors for maintenance and management, several trends may cause their use to grow. The use of lower skilled staff, use of programmable test equipment, automation of data collection and analysis,

condition-based maintenance and the rate of change of technology mitigates against the retention of large numbers of skilled staff in the field. Therefore there may be opportunities for use of contractors, perhaps specialising in certain types of equipment, to carry out some of the functions currently undertaken by utility staff. This change will modify information exchange between utilities and manufacturers.

4.9 Manufacturers

22 manufacturers responded to the questionnaire. Several of the answers belong to the same worldwide manufacturers. If every grouping were to be considered as a single company there would be answers from 15 manufacturers. However, the separate manufacturing units are considered to be separate manufacturers with their own practices, as the answers differ often from the different manufacturing units in the same worldwide group.

Regarding development of protection there is a strong co-operation between manufacturers and large utilities.

Almost all the manufacturers (91%) have input from the utilities when developing a new protection relay. 45% also involve utility personnel in type testing.

A large proportion of manufacturers (82%) seek utility or other third-party approval and all the manufacturers subject new protection relays to system trials with utilities.

The results of the manufacturers replies for maintenance, spares and information are contained in the preceding chapters against the utilities replies.

4.10 Conclusions

The survey of current practices, problems and trends has brought the Working Group to the following overall conclusions.

4.10.1 General

Most utilities are sufficiently well organised to cope with maintenance and management of protection systems autonomously. However all seek manufacturers advice in certain areas, which vary from utility to utility and from manufacturer to manufacturer. There is also wide variation between the relative expectations of utilities and manufacturers. There appears to be a trend towards the adoption of digital technology to make management more efficient. These utilities are looking towards the new functional capabilities of digital protections, use of information technology and access to efficient telecommunication networks to improve their maintenance and management of protection systems. However, there is as yet a lack of operational experience and the support within utilities to move to digital techniques is not yet widely in place. The potential gains however are widely appreciated.

On the other hand, most power systems continue to depend on electro-mechanical and electronic technology to a very large degree so maintenance and management methods will have to enable utilities to cope with these existing systems whilst the new digital technology is being introduced.

4.10.2. Performance Assessment

Most utilities give a high priority to collecting and analysing data on the performance of protection systems during H.V. faults and are well organised to do so. In comparative terms, there is a slightly less emphasis on collecting data to monitor performance during maintenance. It is clear that large grids are monitored more comprehensively than small ones. There is a distinct trend towards the use of digital disturbance recorders and, with their introduction, digital relays to monitor performance coupled with an ability to transfer that information via telecommunication networks to central offices for analysis.

4.10.3 Philosophy

The approach to maintenance, modification, refurbishment and replacement is dependant on the size of the utility, availability of skilled people and access to their suppliers. Whilst some are capable of carrying out relatively complex modification to maintain equipment performance, others, particularly small utilities, will replace equipment at a much earlier stage to achieve the same goal.

High attention is given to the design of protection systems so that maintenance can be easily carried out.

The reliability of protection and new protection principles play an important role in decision making associated with protection replacement.

Whilst utilities already have data bases for installed equipment, there is a trend towards implementation of information system on computers including the calculation of settings.

4.10.4 **Costs and life cycle costs.**

Initial costs of supplying protection systems are kept across almost all utilities, but not necessarily every component of cost. The main components of running costs are not well known and this may be a feature of the availability of the cost data.

Although there is less attention to life cycle costs, approximately half of the utilities have a wish to better control them. A significant aspect of future reduction in costs is expected to be given by a reduction in maintenance time connected with the use of self-checking features. However this expectation is not matched by the manufacturers advice on the need for maintenance and its frequency nor by the intention of utilities on maintenance policy.

4.10.5 **Information**

Transfer of basic documentation from manufacturers to utilities seems to be satisfactory. However there seems to be a reluctance to supply more detailed information on the internal parameters of a relay, especially where software is involved, modifications and upgrades, and reliability. Virtually all utilities keep data on protection systems as installed but relatively few keep these fully up to date with all historical events, possibly because of the difficulties in collecting such information.

The preparation of operating reports on protection behaviour seems to be a fairly common practice. Most utilities have adequate Information Systems, even if they are in whole or in part operated on paper. However the majority of utilities intend to transfer to a computerised system in the next five years. There is a need to improve two way information exchange between utilities and manufacturers, particularly the feedback to manufacturers of the performance of their products during HV faults and maintenance.

4.10.6 **Responsibilities**

Protection system management is generally a centralised activity. In larger utilities regional staff carry directives into effect and form the first link in the feedback chain for performance information.

Whilst protection staff do not normally have responsibility for telecommunication equipment, there is a general appreciation of the importance of telecommunications and the need for both services to work closely together.

Supplier involvement is considered important by utilities and relationships must be based on mutual confidence. Utilities look for assistance to resolve problems as they occur, supply of spare parts, repairs and knowledge of older designs of relays. Manufacturers are less involved in maintenance, performance analysis, maintenance and training. However there does appear to be room for improvement in these areas.

4.10.7 **Maintenance and spares**

Maintenance, repair, modifications, investigation and spare parts managements are normal activities for the utilities. Most apply standard test procedures. An important role is played by the manufacturers in the matter of recommendations for maintenance.

Time intervals for periodic maintenance are between 1 year and more than two years with half of the utilities anticipating no changes in the near future. This is despite a trend towards digital technology where there is meant to be an opportunity to reduce frequency. However, more experience is required before this goal is realised.

Some differences exist between utilities' expectations and manufacturers' offers in matters of spares holding. However as far as the repair time is concerned utilities will only be satisfied if manufacturers really achieve their declared targets which apparently seems to be a problem.

4.10.8 Personnel

A wide diversity in utilities' employment of engineers, technicians and fitters is evident. As a general conclusion protection maintenance and management appears a specialist activity in which technicians find wider type of employment than engineers and fitters. Most utilities do not expect the number of personnel to increase due to the introduction of digital technology, however the trend is likely to be a change in skill level.

Utilities can generally manage their systems independent of manufacturers, their only significant presence is being involved in training activities.

The presence of contractors however could grow with the rapid changes of technology. At the same time the number of skilled staff in the field could go down with automation of data collection and of testing and reduction in maintenance activity.

4.10.9 Manufacturers

Regarding maintenance and management of protection, the manufacturer's role includes giving advice, repairing faulty equipment, training, interchange of information on performance and the need for modification.

Several areas were identified where there appears to be discrepancies between utilities and manufacturers expectations. These are summarised below:

1. Equipment modification and software upgrading.
2. Information to permit control of life cycle costs.
3. Long term product support, especially when software is used.
4. Turn around time for repairs.
5. Supply of performance data from utilities to manufacturers.

There are strong links between utilities and manufacturers during development of new equipment. However, with the wide interest in the use of new technology, there should be discussion on the implications for maintenance and management.

5. FUTURE POSSIBILITIES AND PROBLEMS.

This section examines how future trends may evolve together with other considerations and their consequences.

5.1 Digital Technology

There will continue to be developments in the use of digital technology for protection relays, test equipment, substation control systems, and power system plant monitoring. Much will be linked to the expansion of communications, which will require a standard protocol between relays and substation control equipment. This will present new and more comprehensive opportunities to gather data and better understand and manage the performance of protection, primary plant and the power system itself. Other techniques such as adaptive relaying and expert systems will be introduced thereby widening the horizons still further.

The introduction of such equipments implies that a well defined requirement specification is needed which requires good co-operation between utilities and manufacturers if best use is to be made of it. Power system expansion provides ideal opportunities to introduce these systems in a co-ordinated way, where new substations or major extensions are required. However, it is substation refurbishment that requires careful consideration in order to achieve the same goals and to extend the principles systems wide. The desire to reduce life cycle costs, manage with a different skilled workforce and reduce maintenance time and frequency will affect and be affected by the availability of primary circuit outages. Proper consideration is required before decisions are made on choice of equipment to be installed under expansion or refurbishment schemes.

As equipment becomes more complex and increased integration occurs, field staff will require extensive training or retraining. Special attention will need to be paid to the design of the man machine interface. A standard on international protocol for serial data is required in order to enable the protection and control system designer to work with several manufacturer's equipment and know how to extend and modify them, rather than rely on equipment from a single supplier. This should lead to an improvement in communications between utilities and manufacturers, especially in the area of software support due to rapid evolution. Much can be done to ease the work of the utility engineer based on obtaining and keeping accurate information provided in a standardised format.

5.2 Telecommunications

More communication channels with improved performance will be required to enable a more efficient use of digital technology, such as remote control and reading of settings, remote monitoring of relays internal condition and post fault performance analysis including fault location. Such channels will provide virtually instant access to data within substations from control centres, offices or homes. With suitable protection against unauthorised access (password, etc), they will enable multiple levels of access for control of equipment and plant. Thus maintenance and management techniques will be transformed, from collection of data on paper by skilled staff on site, to automatic collection of data and its transmission to remote points for automatic analysis. It is essential for protection and telecommunication staff to work closely together in this regard, especially in the planning and equipment specification stage in order to provide the necessary data links as power system and management techniques evolve.

5.3 Information Technology (IT)

Advances in the use of IT will enable the utilities to choose the most appropriate systems to meet their needs now and in the future. In association with digital technology in substations and communications, IT has the capability of transforming the maintenance and management of protection. Analysis of all kinds of protection performance will determine appropriate life cycle management and enable better decisions on lifetime, replacement strategy, system design, etc.

This requires extensive data bases to be held by utilities such as network data and topology, characteristics and settings of protection, historical performance data, elements of life cycle costs, etc. Studies of such data bases will enable risk analysis to be undertaken, eg likelihood of a known relay failure mode affecting system reliability. Comparison of data bases requires the information to be provided in a common format.

The ease with which information can be obtained, stored, passed on and analysed will also enable studies of costs and protection system reliability. By understanding these matters utilities will be better able to control them, putting their effort into the areas which will yield the best return.

5.4 Maintenance and Management Policy

The evolution of protection equipment design to optimise maintenance has already been discussed. Another development will be the wider use of self checking which is facilitated by the application of digital relays. This should also include checking of the connections to the relay such as CTs, VTs, and wiring up to the trip coils of circuit breakers. This together with other information will assist in the trend towards a condition based approach to maintenance.

Automatic test equipment is already used by many utilities. The possibility exists to enhance the use of this equipment for diagnostic testing following relay malfunctions during primary system faults. By taking the digital fault recorder data and replaying it into the defective protection, defects may be quickly identified. Automatic analysis of maintenance data produced from a computer test equipment, perhaps by an expert system, will reduce the need to keep paper records of results and can assist in the automatic identification of trends in performance.

Post fault analysis of protection performance, including fault recorder and protection data, will also provide important information for optimisation of protection maintenance. This performance will include the complete protection system, including CTs, VTs, tripping systems and the circuit breaker. Because of the vast amount of data, special software programmes, will be necessary, perhaps using expert systems or artificial intelligence, to carry out the analysis.

The introduction of digital technology

and increased data flow will lead to changes in the organisation of utility protection services. There will be a move towards decentralised maintenance on the one hand and centralised management on the other. Most probably there will also be a change in the way utilities manage their budgets. Where a reduced overall life cycle cost is the goal, an increased investment in IT or equipment replacement cost may be the price to pay. In order to minimise the overall life cycle costs, there is a need for more knowledge of the individual cost elements.

With the evolution of digital protection, the problem of the lifetime of software and its support will become an increasing problem. Manufacturers will introduce modification to overcome software faults and upgrades to add additional functions or improve performance. Utilities would like these changes to occur infrequently so that a level of commonality and standardisation is maintained. Co-operation between manufacturers and utilities are essential in this area to their mutual benefit.

6. FURTHER WORK

In making its consideration the working group became aware of opportunities for further work in this and allied areas. SC34 may wish to consider these alone or in association with other study committees. These areas are listed below.

6.1 Further Surveys

After a suitable period, repeat surveys should be undertaken, particularly to plot the trends identified. They should attempt to be more representative of the worldwide ESI and the questions should be better directed. They should include consideration of the collection of performance and failure data in a standard format.

6.2 Interchange of information

As there is widespread acceptance of the need for better interchange of information, a working group could be set up to determine how to facilitate the exchange both inter-utility and between utilities and manufacturers.

6.3 Refurbishment and Replacement

As there is wide interest in maintaining or improving the performance of protection and substation control systems there could be a study of methods and a guide on the selection of criteria and choice of method to suit particular situations.

6.4 Calculation of Settings

Both to improve the efficiency of this task and to capitalise on the use of digital technology, a study could be made to determine the requirements and infra-structure for calculation and application of settings for protection and control relays.

6.5 Life Cycle Costs

In view of the interest shown in the use of digital technology to control life cycle costs, a study could be made of this subject, in particular to draw manufacturers and users together.

6.6 Training

The wide ranging impact of digital technology, the shift of responsibility between utilities and manufacturers and use of technicians puts a great emphasis on training of all technical staff, worthy of separate study.

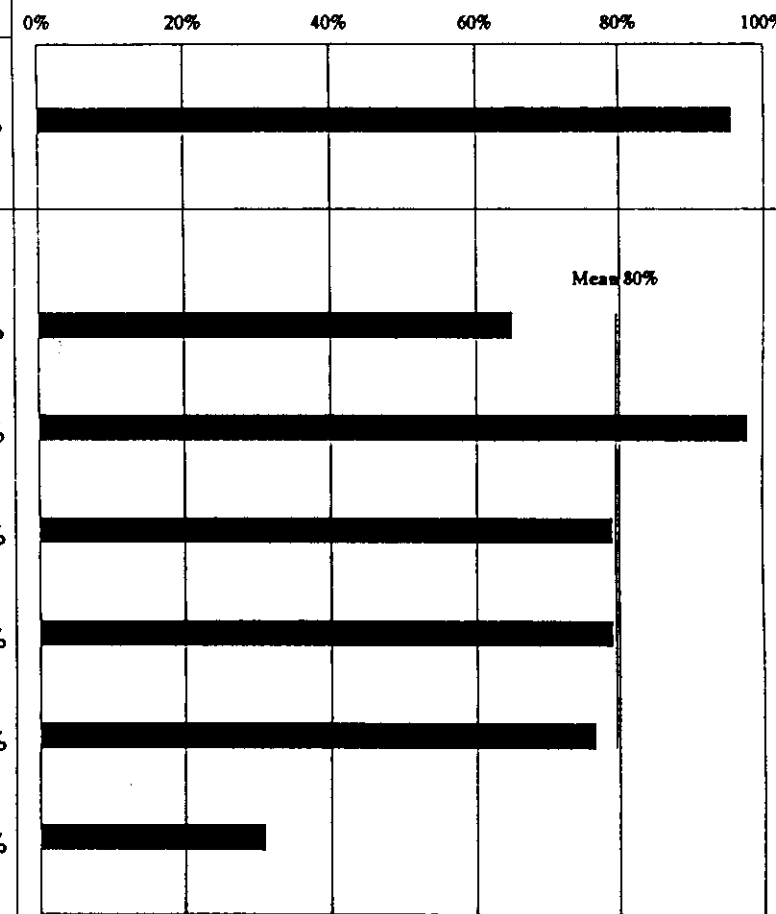
6.7 Maintenance

There is a need to bring utilities and manufacturers together in order to determine the most appropriate criteria for maintenance of protection, especially with the introduction of new technology into existing substations.

UTILITIES QUESTIONAIRE

SECTION 1

Responses to Protection Laboratory		Responses	Yes Answers	Average (%)
1.4.1.	Do you have a test laboratory owned by the utility company?	45	43	96%
	If so, what is its capability:			
1.4.2.	Type testing of protection relays?	43	28	65%
1.4.3.	Investigation of failures?	43	42	98%
1.4.4.	Routine secondary injection?	43	34	79%
1.4.5.	Repair and retest of relays?	43	34	79%
1.4.6.	Spares holding?	43	33	77%
1.4.7.	Any other	45	14	31%

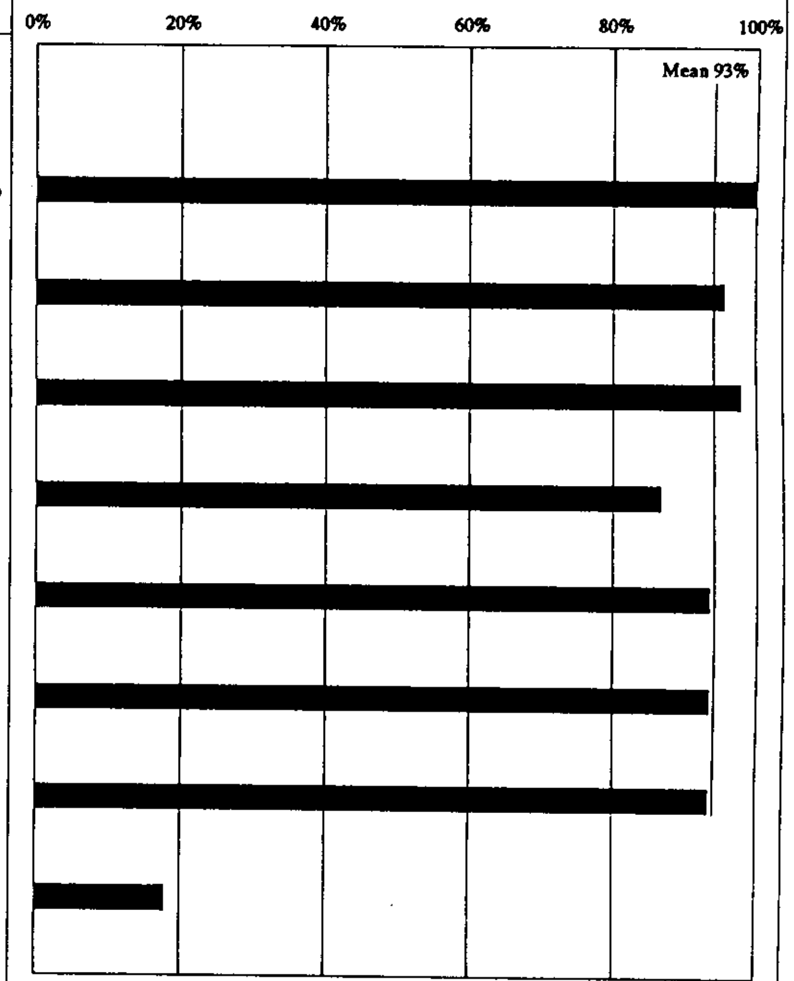


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 2

Responses To Performance Assessment Data collection		Responses	Yes' Answers	Average (%)
	Do you systematically gather information about:			
	H.V. Fault itself:			
2.a.1.1.	Time (day, hour)?	45	45	100%
2.a.1.2.	Cause?	45	43	96%
2.a.1.3.	Phase(s)?	45	44	98%
2.a.1.4.	Fault current clearance time?	45	39	87%
2.a.1.5.	Automatic reclosing?	45	42	93%
2.a.1.6.	Alarms in substations, in dispatching?	45	42	93%
2.a.1.7.	Reaction of the grid? (measurements, grids situation, loss of protection, loss of load)	45	42	93%
2.a.1.8.	Other	45	8	18%

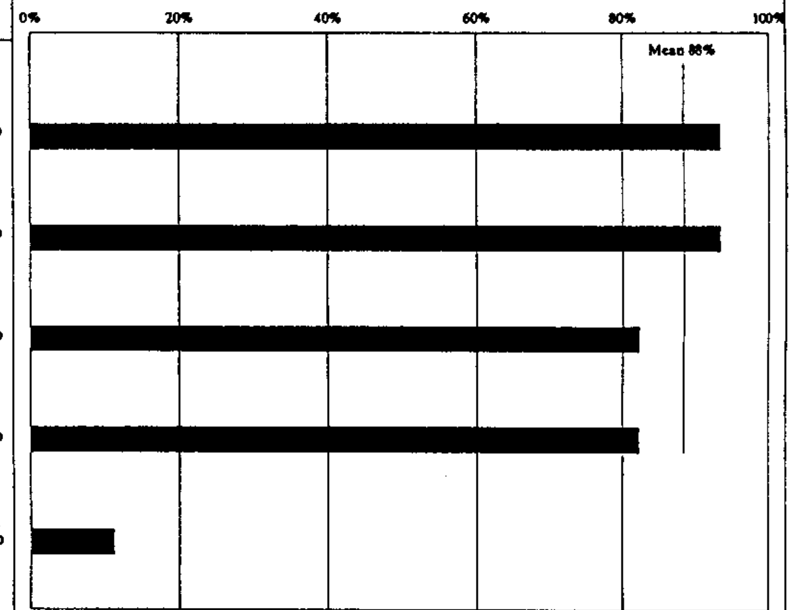


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 2

Responses To Performance Assessment Data collection		Responses	Yes Answers	Average (%)
	Behaviour of Protection During H.V. Faults:			
2.a.2.1.	Event and analog recording?	45	42	93%
2.a.2.2.	Indications on the relays?	45	42	93%
2.a.2.3.	Operating time of protection(s)?	45	37	82%
2.a.2.4.	Reaction of other protection which respond to the fault	45	37	82%
2.a.2.5.	Any other?	45	5	11%

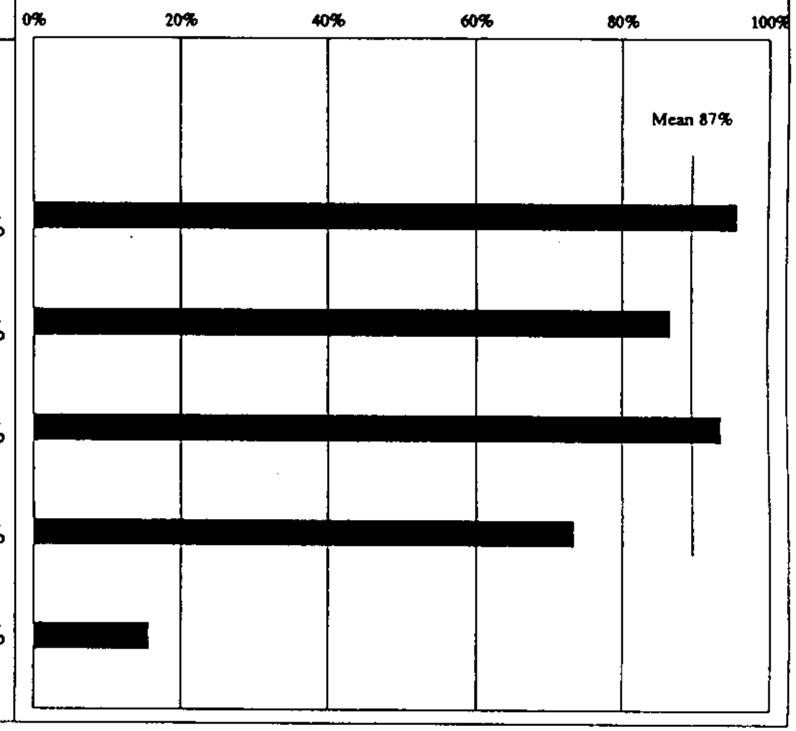


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 2

Responses To Performance Assessment Data collection		Responses	Yes Answers	Average (%)
	Behaviour of the protection relays during maintenance tests or post–incident tests:			
	Kind of failure:			
2.a.3.1.	Type of relay	45	43	96%
2.a.3.2.	Card or device?	45	39	87%
2.a.3.3.	Description of failure?	45	42	93%
2.a.3.4.	Consequences of failure?	45	33	73%
2.a.3.5.	Any other?	45	7	16%

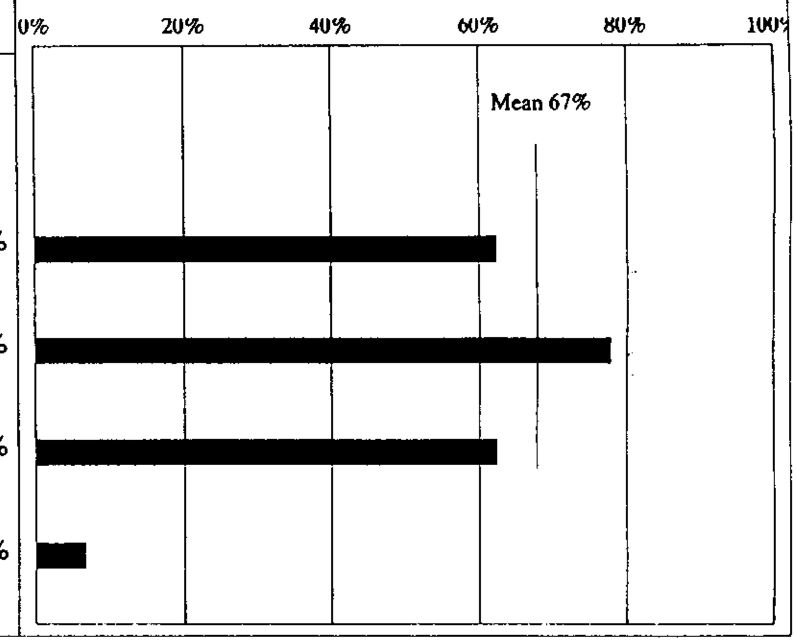


CIGRÉ WG 34−06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 2

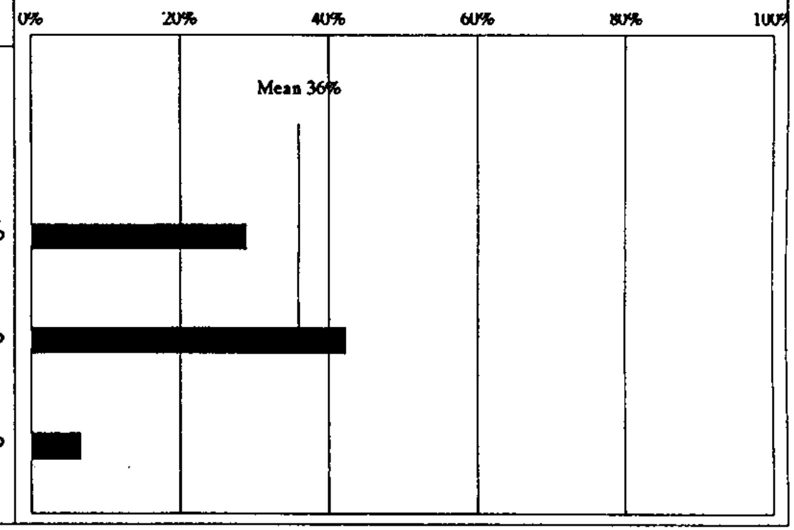
Responses To Performance Assessment Data collection		Responses	Yes Answers	Average (%)
	Behaviour of the protection relay during maintenance tests or post−incident tests: Repair:			
2.a.3.6.	Replacement card or component?	45	28	62%
2.a.3.7.	Replacement relay or part of a relay?	45	35	78%
2.a.3.8.	Repaired in−house or by manufacturer?	45	28	62%
2.a.3.9.	Any other?	45	3	7%



UTILITIES QUESTIONAIRE

SECTION 2

Responses To Performance Assessment Data collection		Responses	Yes Answers	Average (%)
	Unavailability of protection: (line–, transformer–, busbar protection, breaker failure protection, teleprotection, ...)			
2.a.4.1.	Time of unavailability?	45	13	29%
2.a.4.2.	Impact of unavailability during H.V. faults?	45	19	42%
2.a.4.3.	Any other	45	3	7%

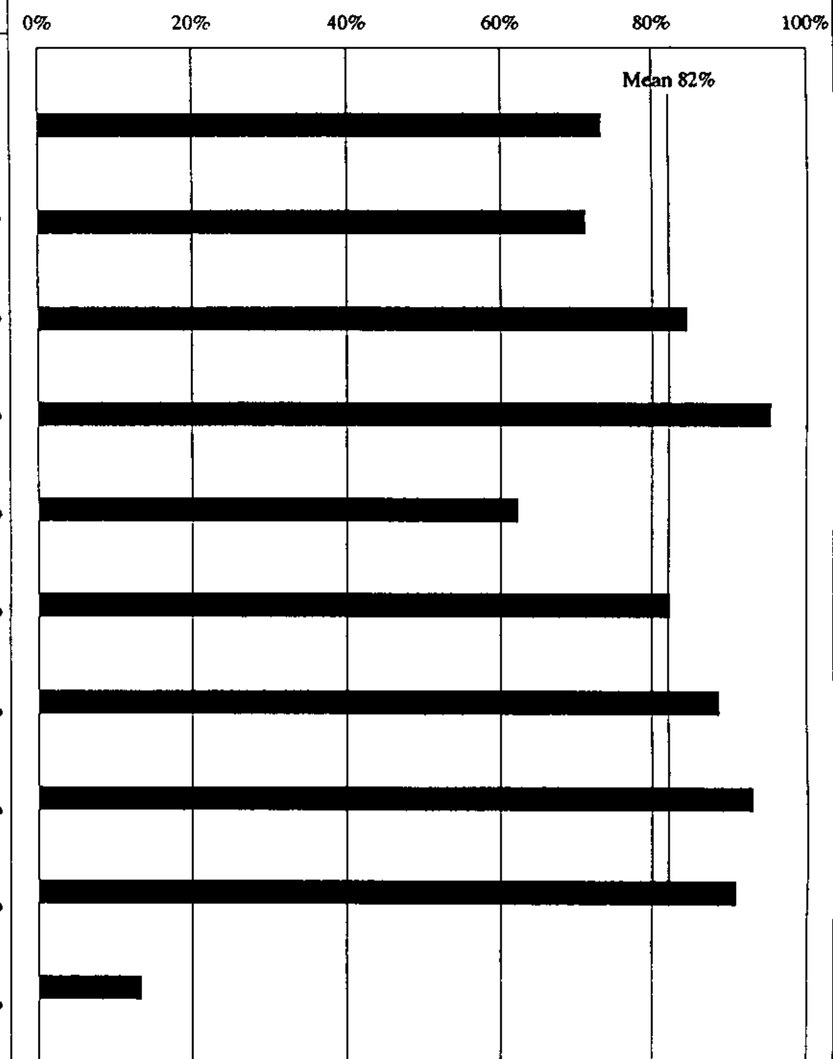


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 2

Performance Assessment Analysis of H.V. Faults		Responses	Yes Answers	Average (%)
	Do you keep statistics of:			
2.b.1.1.	Restoration time?	45	33	73%
2.b.1.2.	Type of restoration? (manual local/remote, automatic)	45	32	71%
2.b.1.3.	Automatic reclosing effectiveness?	45	38	84%
2.b.1.4.	Unwanted trippings?	45	43	96%
2.b.1.5.	Fault current clearance time of H.V. faults?	45	28	62%
2.b.1.6.	Number of 1, 2 or 3 phase faults?	45	37	82%
2.b.1.7.	Cause of H.V. faults?	45	40	89%
2.b.1.8.	Incorrect operations of relays?	45	42	93%
2.b.1.9.	Reasons for incorrect operations?	45	41	91%
2.b.1.10.	Any other	45	6	13%

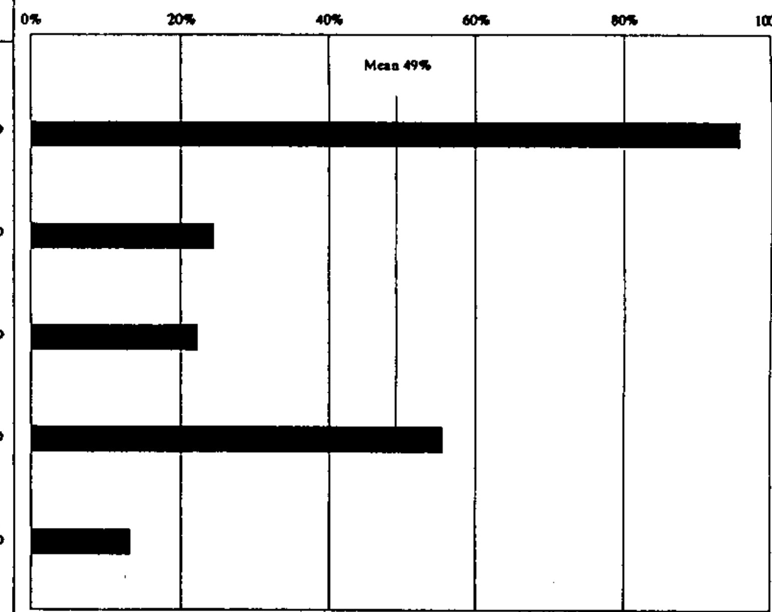


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 2

Performance Assessment Analysis of H.V. Faults		Responses	Yes Answers	Average (%)
	To whom do you release this data:			
2.b.2.1.	Within the utility?	45	43	96%
2.b.2.2.	To international organisations, eg. CIGRÉ?	45	11	24%
2.b.2.3.	To equipment manufacturers?	45	10	22%
2.b.2.4.	Available to others who request it?	45	25	56%
2.b.2.5.	Any others?	45	6	13%

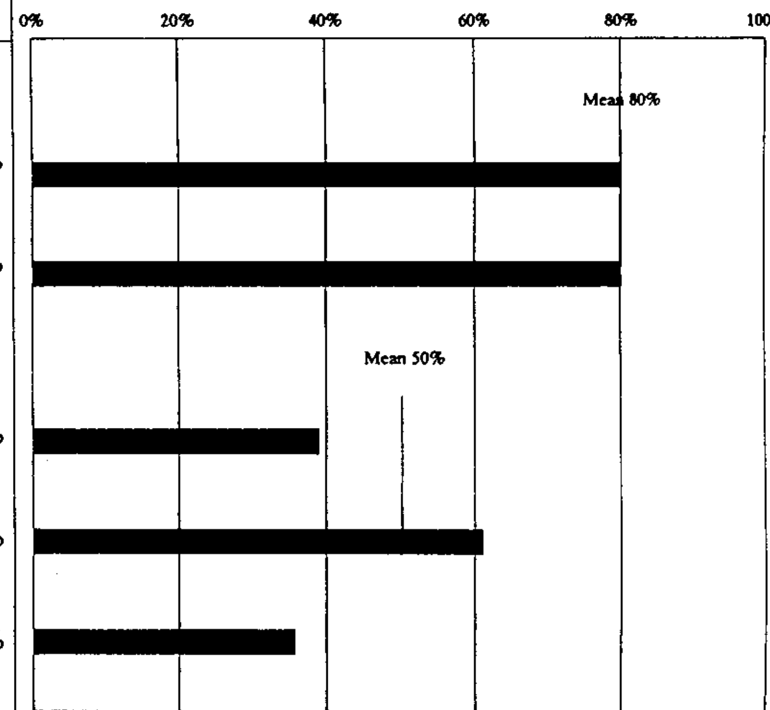


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 3

Philosophy Modification of Equipment		Responses	Yes Answers	Average (%)
	Do you carry out systematic modification of all relays of the same type			
3.a.1.	After incorrect operation discovered by utility (or its laboratory)?	45	36	80%
3.a.2.	On advise from supplier?	45	36	80%
	Do you get this advise:			
3.a.2.1.	On a regular basis?	36	14	39%
3.a.2.2.	On request?	36	22	61%
3.a.3.	Refurbishment only to cope with new objectives or new protection principles.	45	16	36%

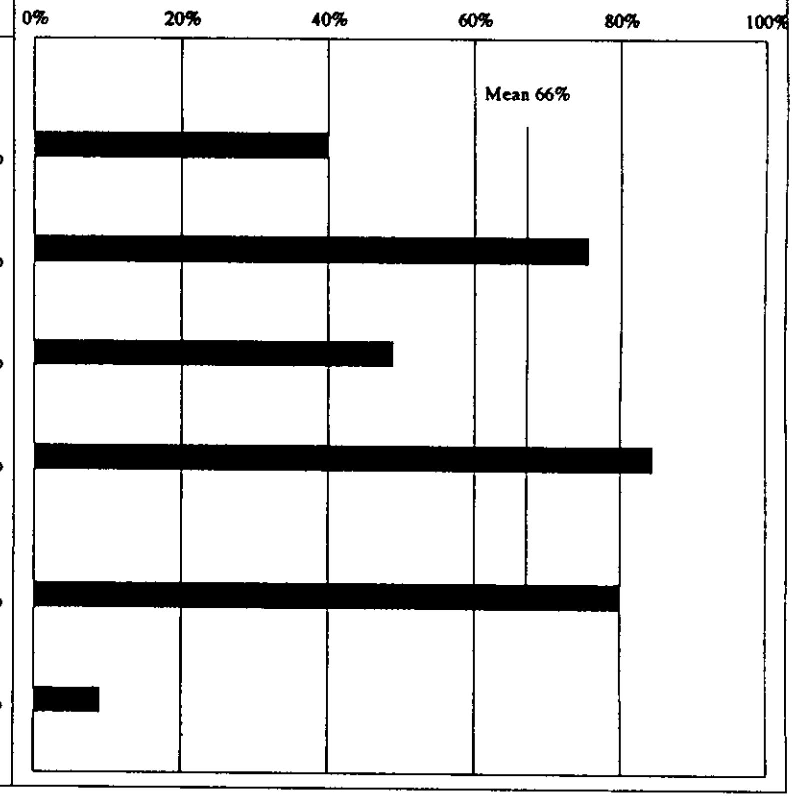


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 3

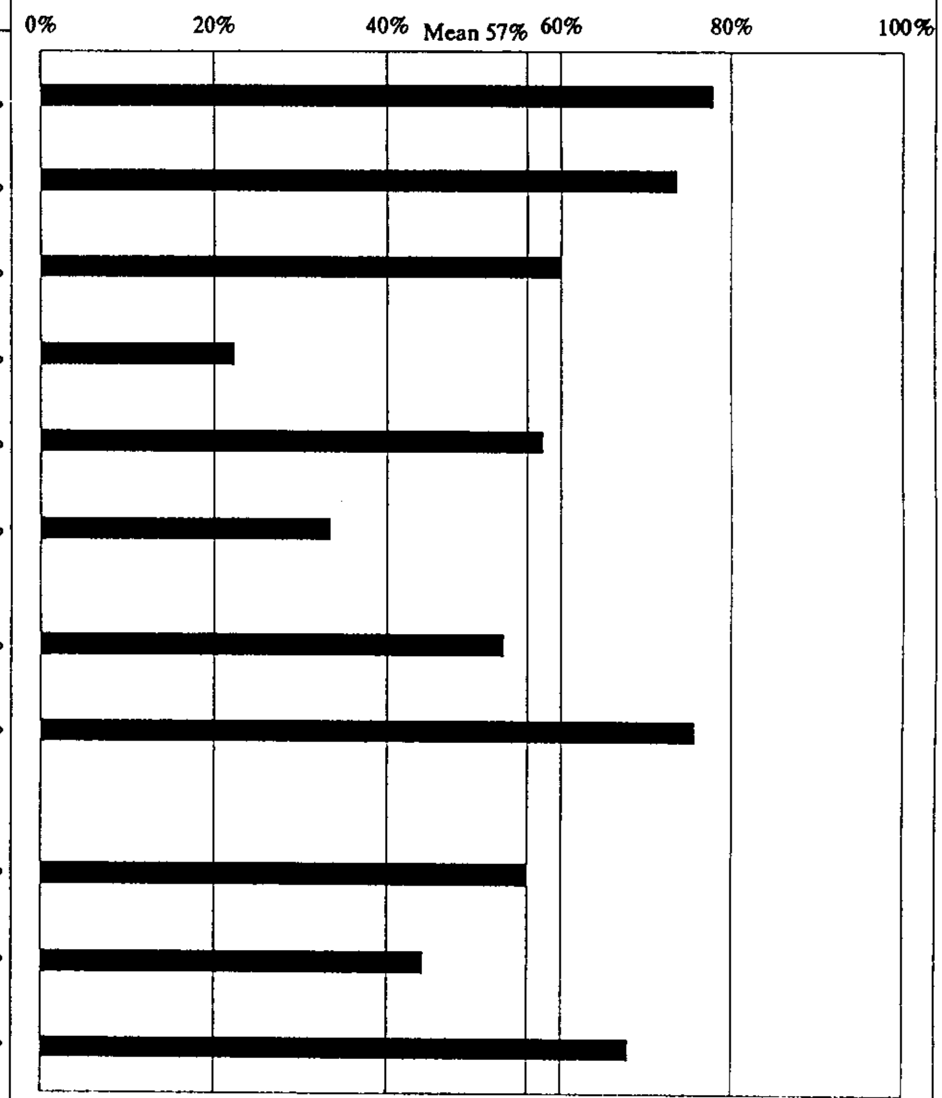
Philosophy Replacement of Equipment		Responses	Yes Answers	Average (%)
	Do you replace protection equipment in the following situations:			
3.b.1.	After incorrect operation stated by the utility?	45	18	40%
3.b.2.	When repeated problems are investigated during maintenance?	45	34	76%
3.b.3.	When spares are no longer available?	45	22	49%
3.b.4.	When the tripping time or sensitivity of the relay gets beyond a certain limit or when increasing degradation is observed?	45	38	84%
3.b.5.	When relays are required to cope with new protection principles or characteristics?	45	36	80%
3.b.6.	Any other?	45	4	9%



UTILITIES QUESTIONAIRE

SECTION 3

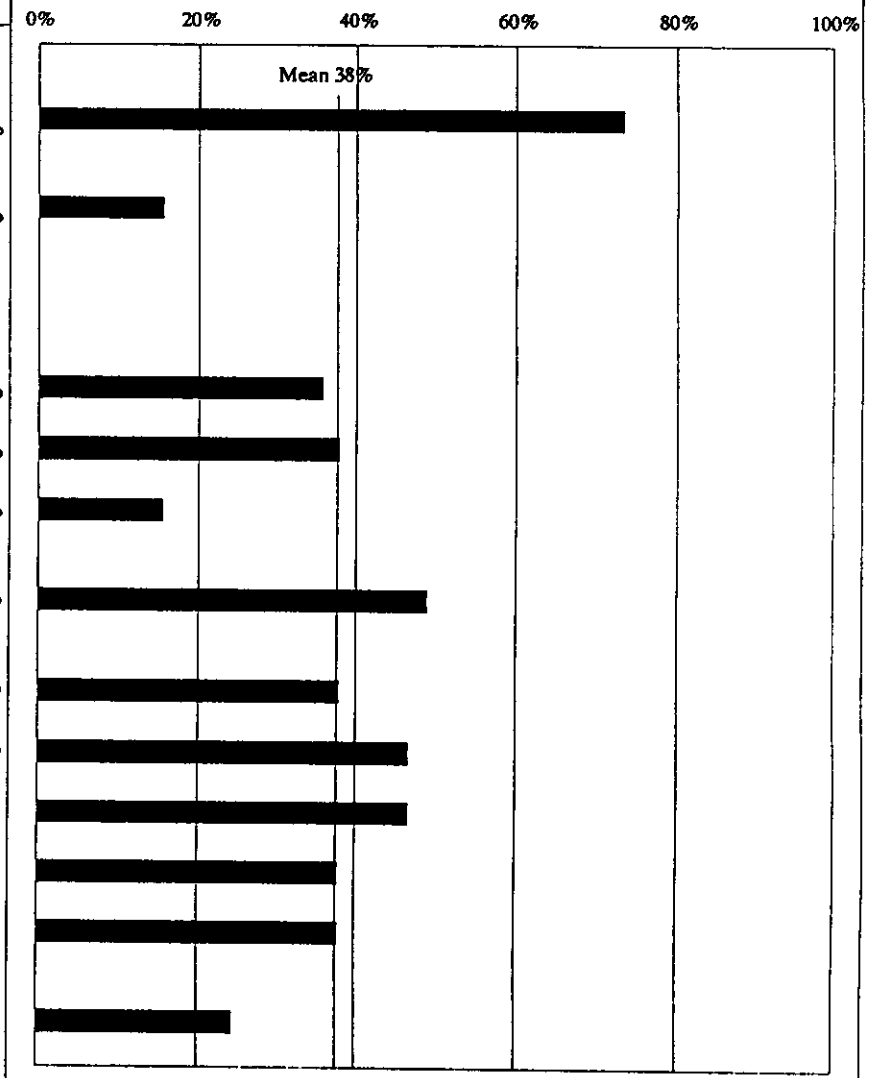
Philosophy Providing For Maintenance in the Design		Responses	Yes Answers	Average (%)
3.c.1.	Are your protection cubicals designed such that maintenance tests can be easily executed?	45	35	78%
3.c.2.	Are there test connectors for each protection relay?	45	33	73%
3.c.3.	Are there test connectors for each protection system?	45	27	60%
3.c.4.	Are there test connectors for automatic control equipment?	45	10	22%
3.c.5.	Is the type of the test connectors standardized and independant of the supplier of the relays?	45	26	58%
3.c.6.	Does the maintenance crew have to disconnect wires or remove links in order to perform normal maintenance tests?	45	15	33%
3.c.7.	Do you have a standard design of the protection cubicles incorporating test facilities?	45	24	53%
3.c.8.1.	Can you easily maintain protection with the circuit on load?	45	34	76%
	If so, how do you isolate the trip output:			
3.c.8.2.	by switch?	34	19	56%
3.c.8.3.	by link?	34	15	44%
3.c.8.4.	via test block?	34	23	68%



UTILITIES QUESTIONAIRE

SECTION 4

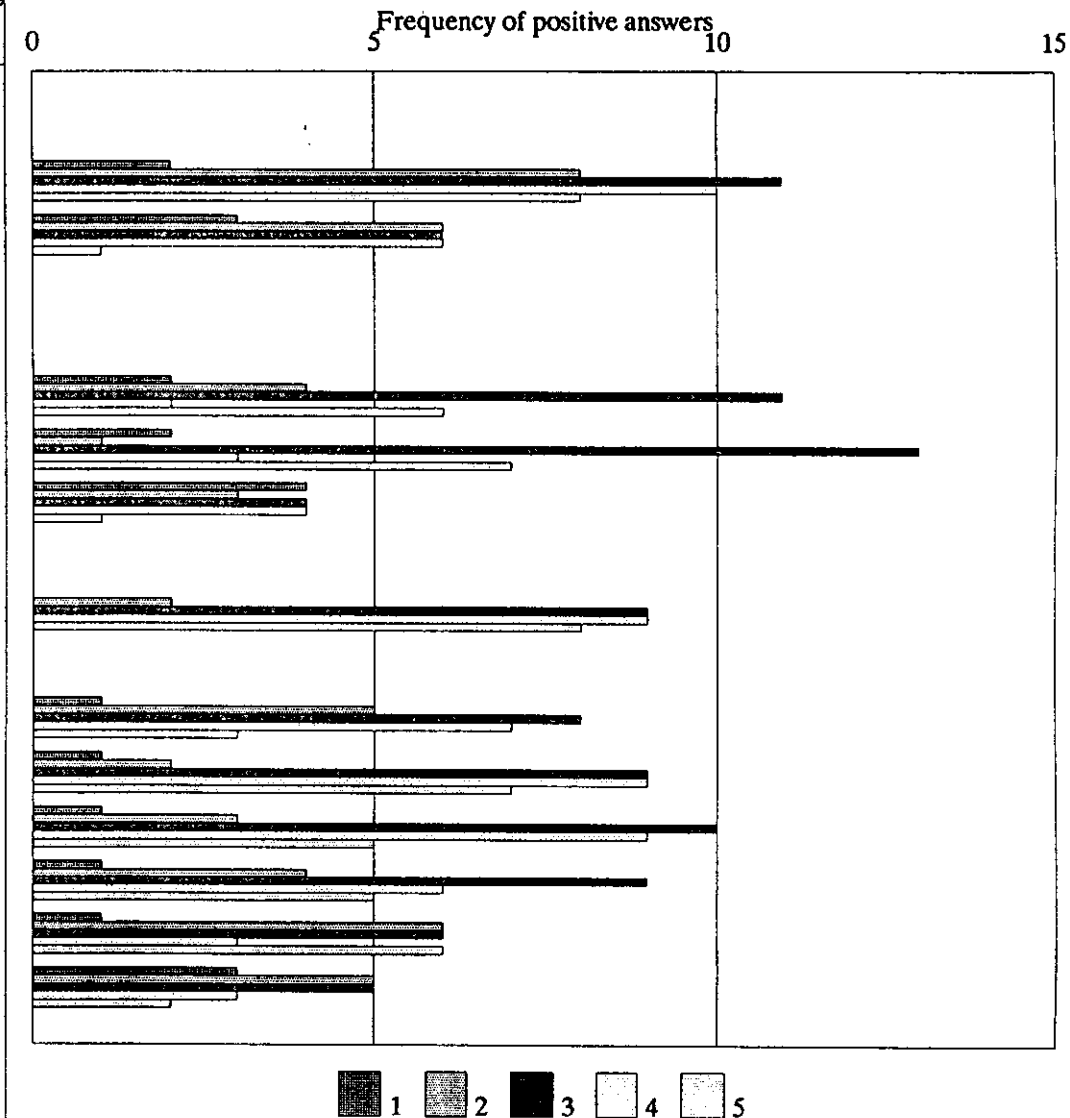
Costs		Responses	Yes Answers	Average (%)
	Do you keep a record of the following?			
4.1.1.	Cost of new protection relays?	45	33	73%
4.1.2.	Cost of introduction of new protection relays (type–testing, training, ...)?	45	7	16%
4.2.	Cost of protection work:			
4.2.1.	due to protection refurbishment?	45	16	36%
4.2.2.	due to extensions of the grid?	45	17	38%
4.2.3.	due to lifetime management?	45	7	16%
4.3.	Total cost of new protection cubicles?	45	22	49%
	or broken down into:			
4.3.1.	design of schemes?	45	17	38%
4.3.2.	purchase relays & cubicles?	45	21	47%
4.3.3.	installation on site?	45	21	47%
4.3.4.	tests at supplier and on site?	45	17	38%
4.3.5.	building to house protection equipment?	45	17	38%
4.3.6.	in–house overheads for construction activity?	45	11	24%



UTILITIES QUESTIONAIRE

SECTION 4

Costs		Responses	Importance Total	Importance Average
	How important are the following: (On a scale of 1 to 5)			
4.1.1.	Cost of new protection relays?	39	131	3
4.1.2.	Cost of introduction of new protection relays (type–testing, training, ...)?	22	62	3
4.2.	Cost of protection work:			
4.2.1.	due to protection refurbishment?	25	81	3
4.2.2.	due to extensions of the grid?	26	90	3
4.2.3.	due to lifetime management?	16	43	3
4.3.	Total cost of new protection cubicles?	28	107	4
	or broken down into:			
4.3.1.	design of schemes?	24	78	3
4.3.2.	purchase relays & cubicles?	28	103	4
4.3.3.	installation on site?	28	98	4
4.3.4.	tests at supplier and on site?	25	85	3
4.3.5.	building to house protection equipment?	22	73	3
4.3.6.	in–house overheads for construction activity?	18	50	3



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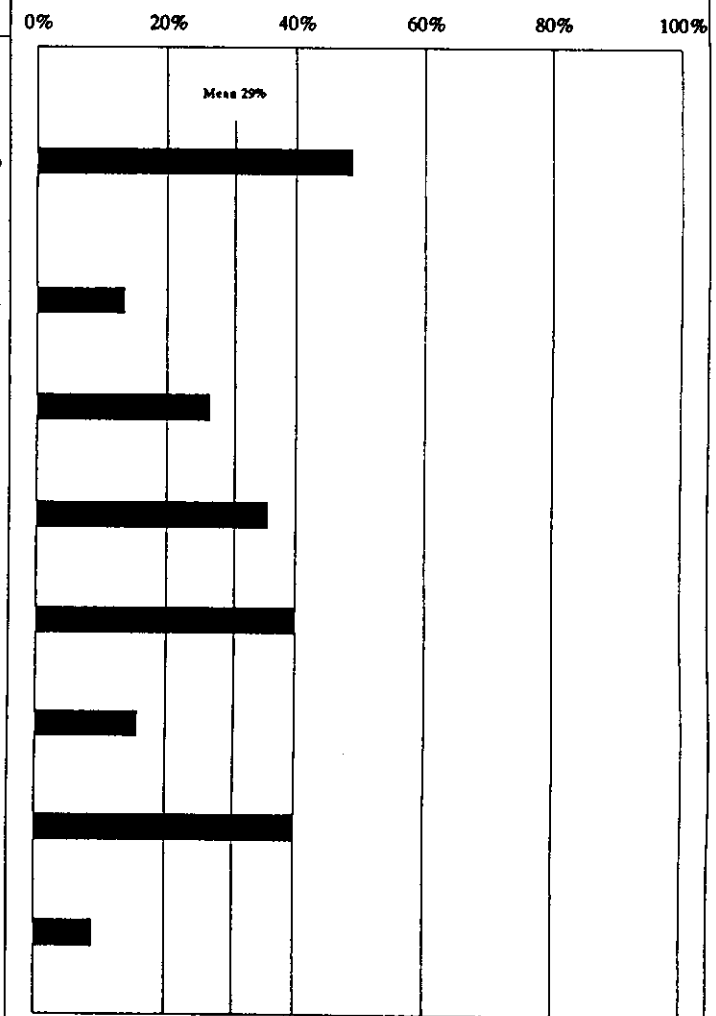
UTILITIES QUESTIONAIRE

SECTION 4

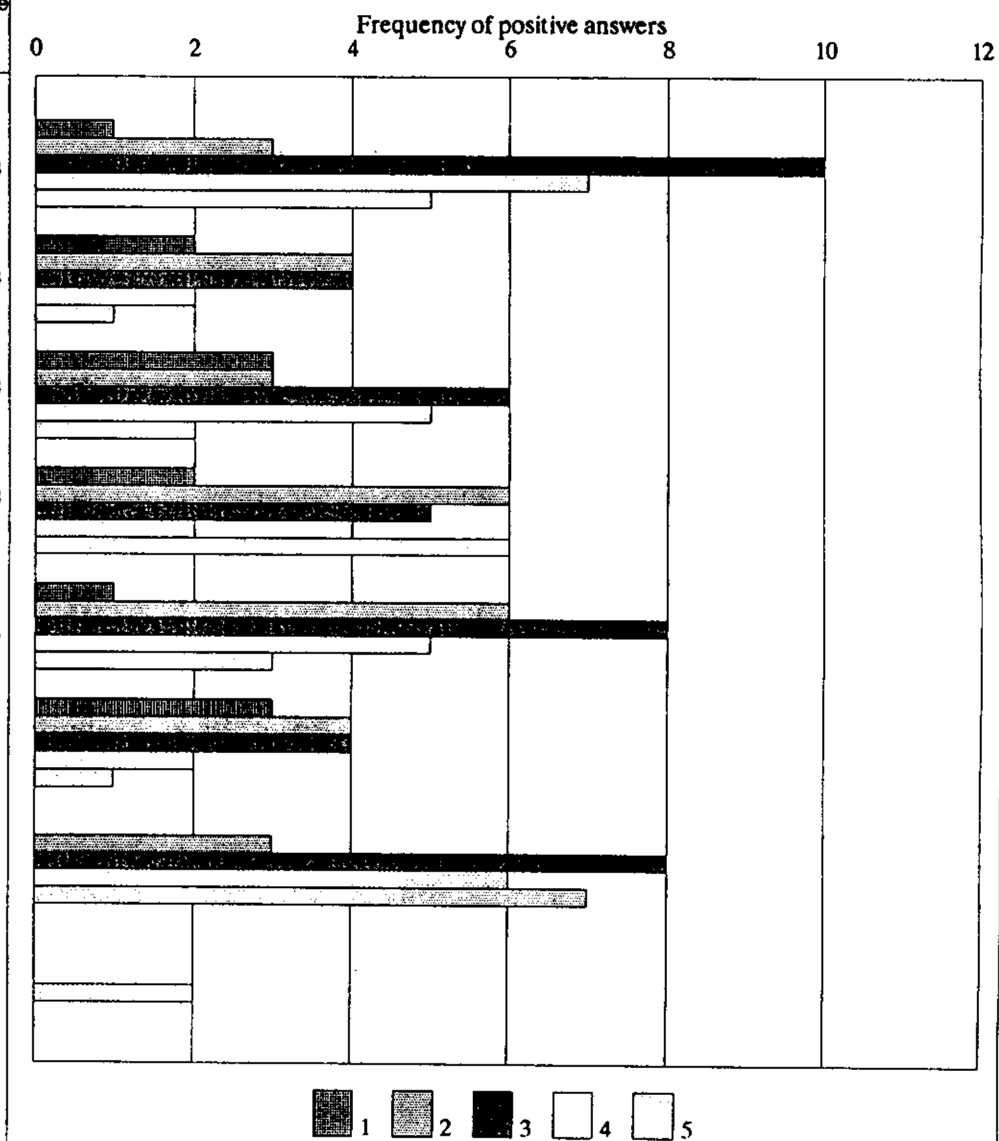
Costs		Responses	Yes Answers	Average (%)
	Do you keep a record of the following:			
4.4.1.	Total manhours performed and other costs of maintenance:	45	22	49%
	Broken down into:			
4.4.2.	per cubicle?	45	6	13%
4.4.3.	per primary circuit?	45	12	27%
4.4.4.	per substation?	45	16	36%
4.5.	Purchase of spares?	45	18	40%
4.6.	Turnover of spares?	45	7	16%
4.7.	Cost of running a "Protection Department"?	45	18	40%
4.8.	Any other	45	4	9%



UTILITIES QUESTIONAIRE

SECTION 4

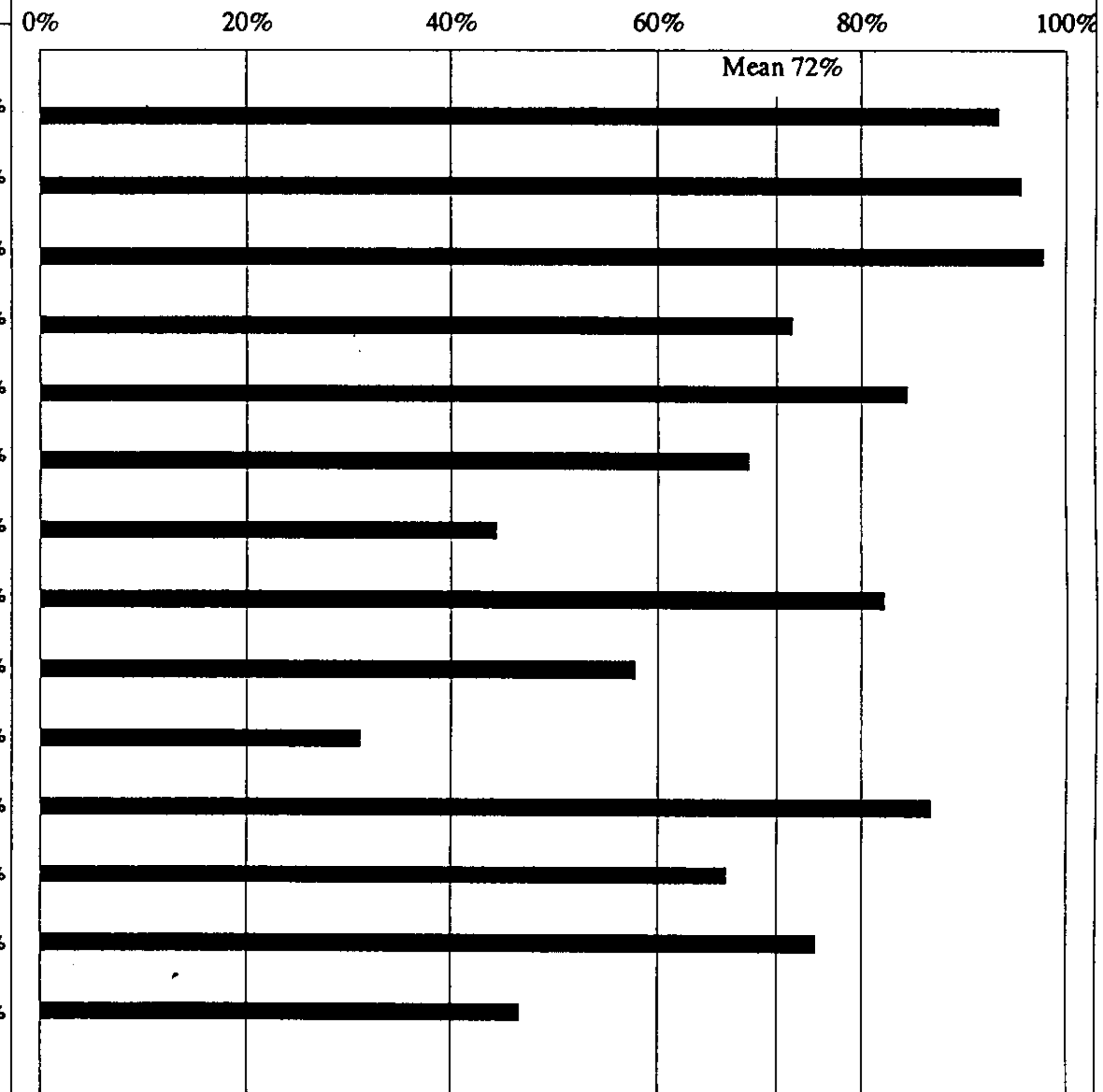
Costs		Responses	Importance Total	Importance Average
	How important are the following: (On a scale of 1 to 5)			
4.4.1.	Total manhours performed and other costs of maitenance:	26	90	3
	or broken down into:			
4.4.2.	per cubicle?	13	35	3
4.4.3.	per primary circuit?	19	57	3
4.4.4.	per substation?	21	67	3
4.5	purchase of spares?	23	72	3
4.6.	turnover of spares?	14	36	3
4.7.	cost of running a "Protection Department"? (for design, application, calculations, investigations, approvals, etc.)	24	89	4
4.8.	Any other	2	8	4



UTILITIES QUESTIONAIRE

SECTION 5

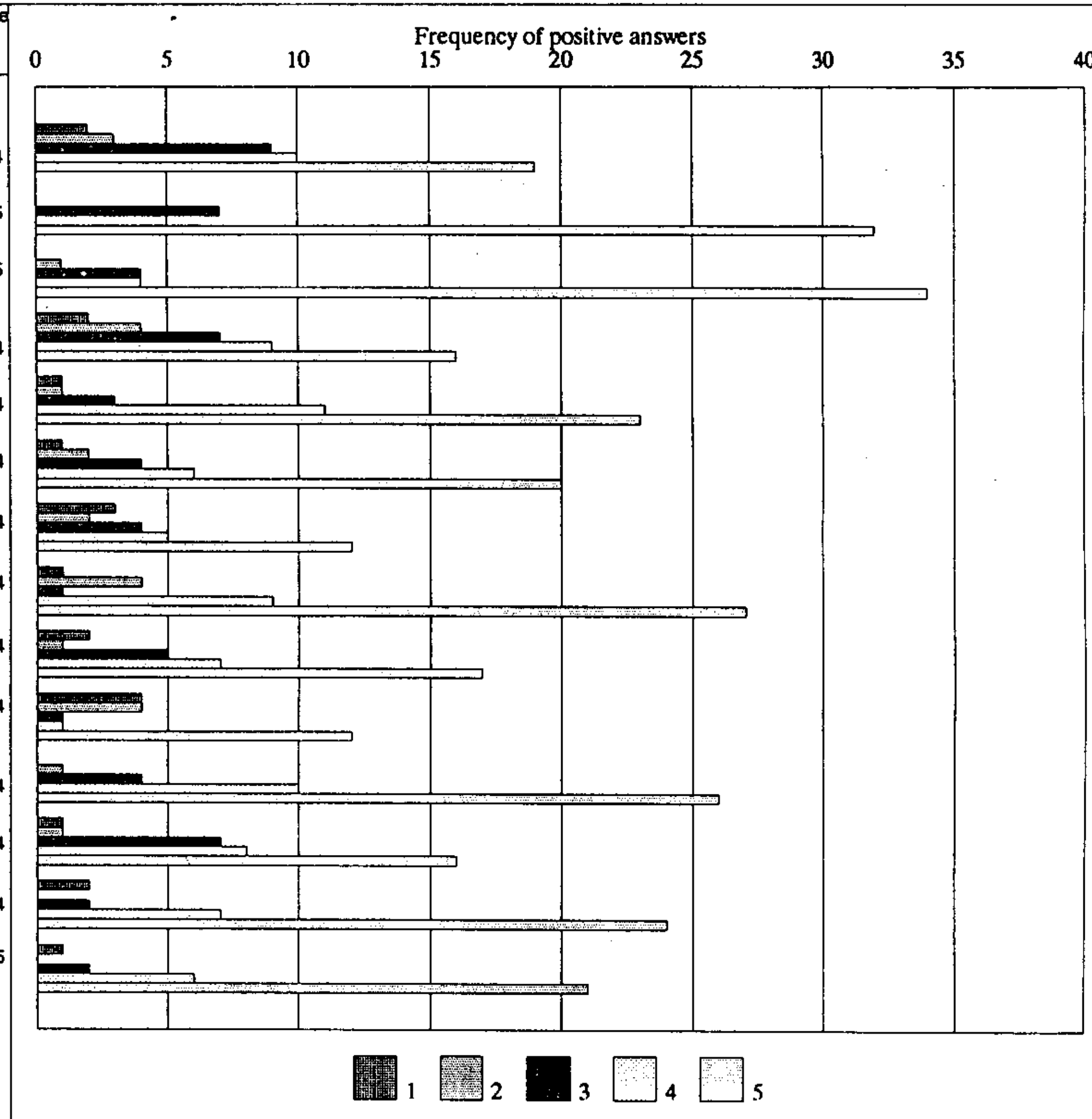
Information: Information From the Supplier		Responses	Yes Answers	Average (%)
	Do you keep a record of the following?			
5.a.1.	Range of products and possible applications?	45	42	93.3%
5.a.2.	Operating principles?	45	43	95.6%
5.a.3.	Commissioning, operation and maintenance manual?	45	44	97.8%
5.a.4.	Test reports?	45	33	73.3%
5.a.5.	List of all devices within the protection?	45	38	84.4%
5.a.6.	List of all cards within the protection?	45	31	68.9%
5.a.7.	List of all components on the cards?	45	20	44.4%
5.a.8.	Relay internal connection diagram?	45	37	82.2%
5.a.9.	Flow chart of software?	45	26	57.8%
5.a.10.	Source of software program: release reference?	45	14	31.1%
5.a.11.	Proposal from the supplier for: external connection of the relay?	45	39	86.7%
5.a.12	relay optional connection?	45	30	66.7%
5.a.13.	setting of the relay?	45	34	75.6%
5.a.14.	Systematic information from the supplier about every modification on the type of relay?	45	21	46.7%



UTILITIES QUESTIONAIRE

SECTION 5

Information: Information From the Supplier		Responses	Importance Total	Importance Average
	How important are the following: (On a scale of 1 to 5)			
5.a.1.	Range of products and possible applications?	43	170	4
5.a.2.	Operating principles?	44	201	5
5.a.3.	Commissioning, operation and maintenance manual?	43	200	5
5.a.4.	Test reports?	38	147	4
5.a.5.	List of all devices within the protection?	39	171	4
5.a.6.	List of all cards within the protection?	33	141	4
5.a.7.	List of all components on the cards?	26	99	4
5.a.8.	Relay internal connection diagram?	42	183	4
5.a.9.	Flow chart of software?	32	132	4
5.a.10.	Source of software program: release reference?	22	79	4
	Proposal from the supplier for:			
5.a.11.	external connection of the relay?	41	184	4
5.a.12	relay optional connection?	33	136	4
5.a.13.	setting of the relay?	35	156	4
5.a.14.	Systematic information from the supplier about every modification on the type of relay?	30	136	5



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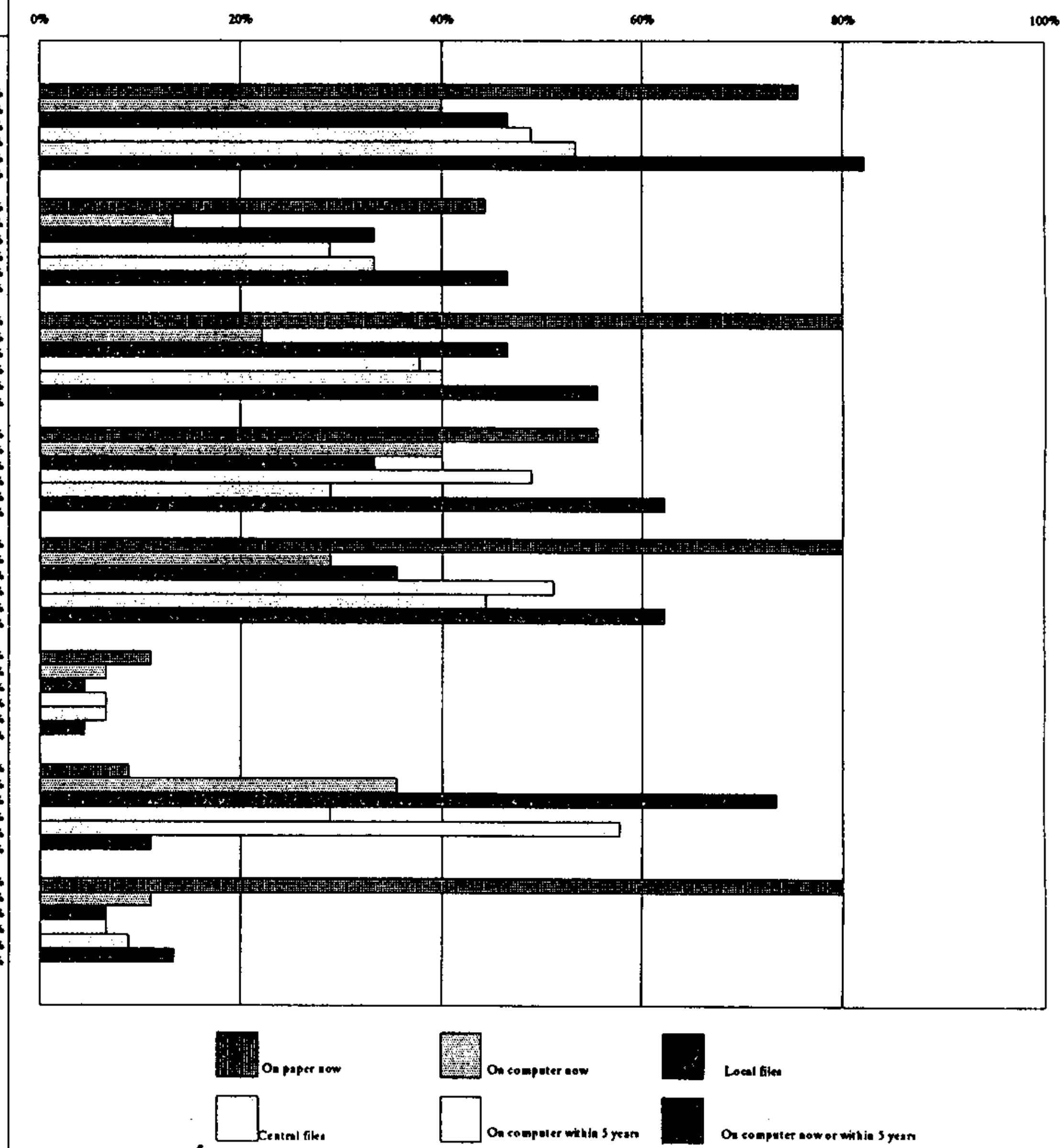
UTILITIES QUESTIONAIRE

SECTION 5

Information: In House Information		Responses	Yes Answers	Average (%)
	Do you keep records of the following items and if yes, how do you store them?			
5.b.1.	Type, mark, age, rating, range, etc.	45	34	76%
		45	18	40%
		45	21	47%
		45	22	49%
		45	24	53%
		45	37	82%
5.b.2.	Historical overview of each protection relay.	45	20	44%
		45	6	13%
		45	15	33%
		45	13	29%
		45	15	33%
		45	21	47%
5.b.3.	Maintenance reports.	45	36	80%
		45	10	22%
		45	21	47%
		45	17	38%
		45	18	40%
		45	25	56%
5.b.4.	Operation (correct & incorrect) reports.	45	25	56%
		45	18	40%
		45	15	33%
		45	22	49%
		45	13	29%
		45	28	62%
5.b.5.	Setting calculations.	45	36	80%
		45	13	29%
		45	16	36%
		45	23	51%
		45	20	44%
		45	28	62%
5.b.6.	Any other.	45	5	11%
		45	3	7%
		45	2	4%
		45	3	7%
		45	3	7%
		45	2	4%
5.b.7.	Grid characteristics of lines, cables, transformer (R, X, L)	45	4	9%
		45	16	36%
		45	33	73%
		45	13	29%
		45	26	58%
		45	5	11%
5.b.8.	Any other.	45	36	80%
		45	5	11%
		45	3	7%
		45	3	7%
		45	4	9%
		45	6	13%

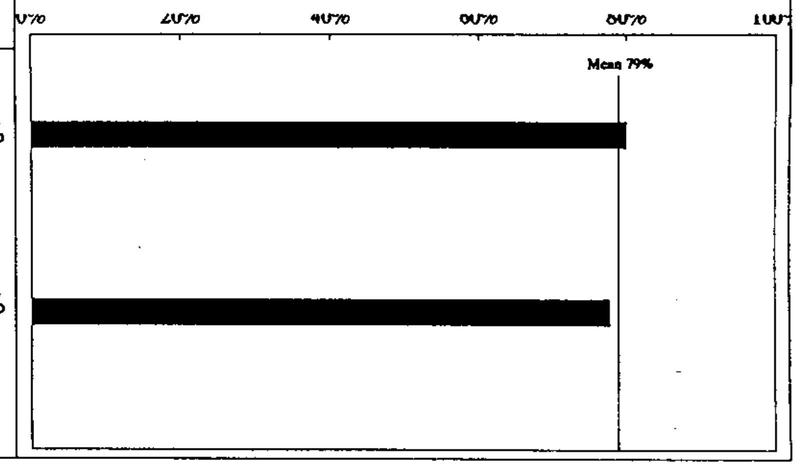


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 5

Information Calculation of Settings		Responses	Yes Answers	Average (%)
5.c.1.	Do you have, or do you forsee having in the next 5 years computer programs to calculate the primary settings of the relays?	45	36	80%
5.c.2.	Do you have, or do you forsee having in the next 5 years computer programs to calculate the secondary settings of the relays?	45	35	78%

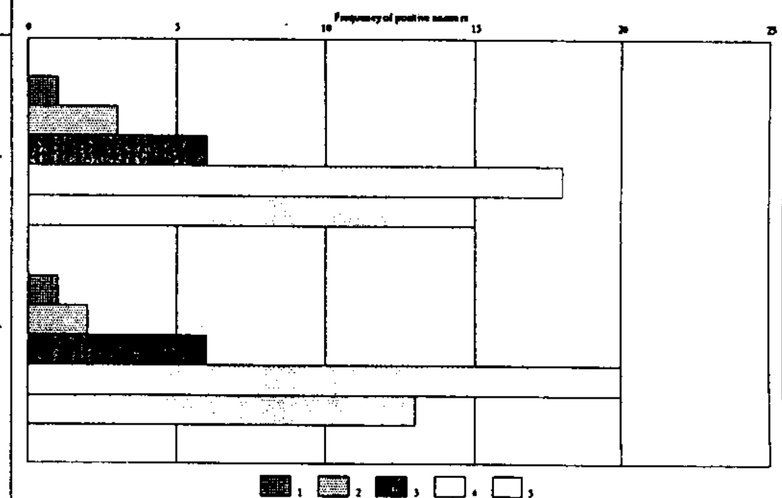


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 5

Information: Calculation of Settings		Responses	Importance Total	Importance Average
	How important are the following: (On a scale of 1 to 5)			
5.c.1.	Do you have, or do you forsee having in the next 5 years computer programs to calculate the primary settings of the relay?	43	172	4
5.c.2.	Do you have, or do you forsee having in the next 5 years computer programs to calculate the secondary settings of the relay?	42	168	4

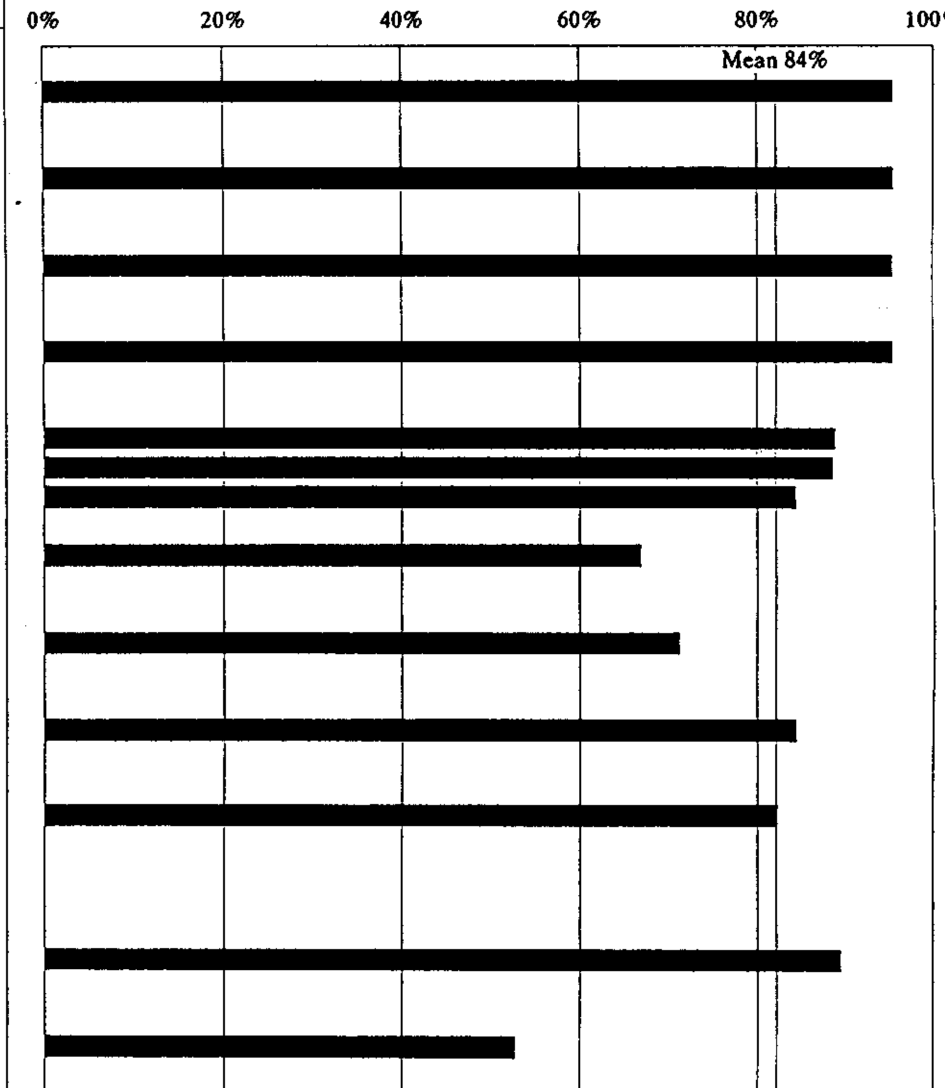


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 6

Responsibilities Protection Department		Responses	Yes Answers	Average (%)
	Do you have a central "Protection Dept." that:			
6.a.1.	Determines company policy?	45	43	96%
6.a.2.	Introduces new techniques?	45	43	96%
6.a.3.	Approves use of specific relays?	45	43	96%
6.a.4.	Choose relays for specific applications?	45	43	96%
6.a.5.	Calculates settings: of G1?	36	32	89%
	of G2?	44	39	89%
	of G3?	32	27	84%
6.a.6.	Plans maintenance?	45	30	67%
6.a.7.	Trains maintenance crews?	45	32	71%
6.a.8.	Produces commissioning procedures?	45	38	84%
6.a.9.	Produces maintenance procedures?	45	37	82%
	Are these procedures made:			
6.a.10.	In coordination with the maintenance crew?	38	34	89%
6.a.11.	In coordination with the supplier, laboratory?	38	20	53%

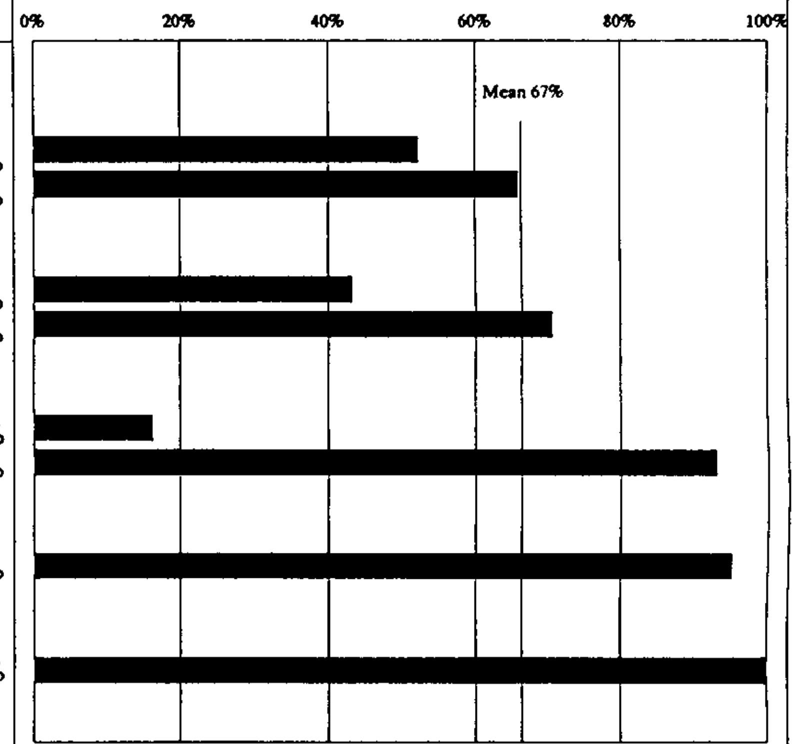


CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 6

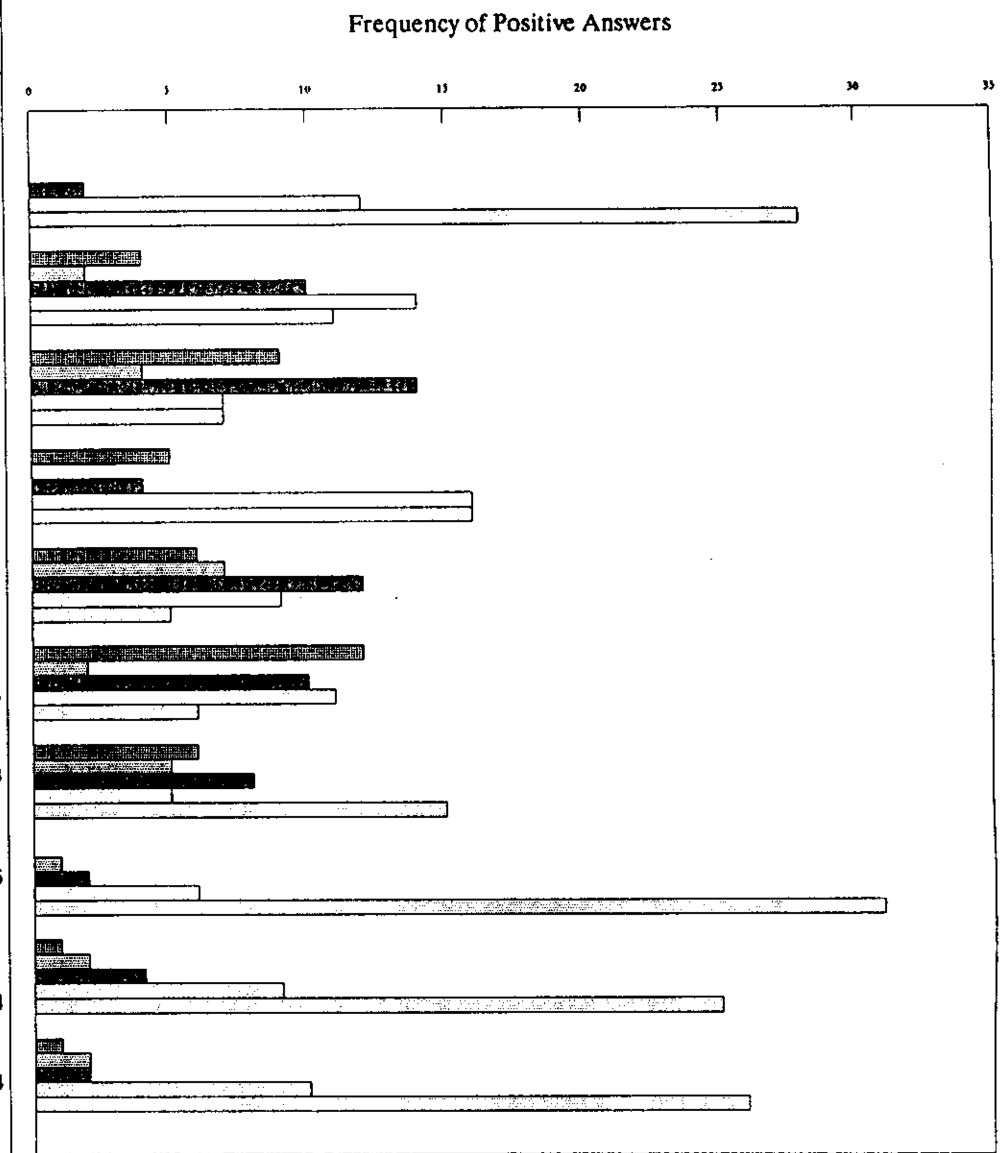
Responsibilities Telecom and Protection		Responses	Yes Answers	Average (%)
	Which service is responsible for:			
6.b.1.	Commissioning of teleprotection equipment?			
	Protection:	44	23	52%
	Telecoms:	44	29	66%
6.b.2.	Maintenance of teleprotection equipment?			
	Protection:	44	19	43%
	Telecoms:	44	31	70%
6.b.3.	Communication links used by protections?			
	Protection:	43	7	16%
	Telecoms:	43	40	93%
6.b.4.	Is there a decentralised close relationship between the Protection service and the Telecom service?	41	39	95%
6.b.5.	Do you think this relationship is essential?	41	41	100%



UTILITIES QUESTIONAIRE

SECTION 6

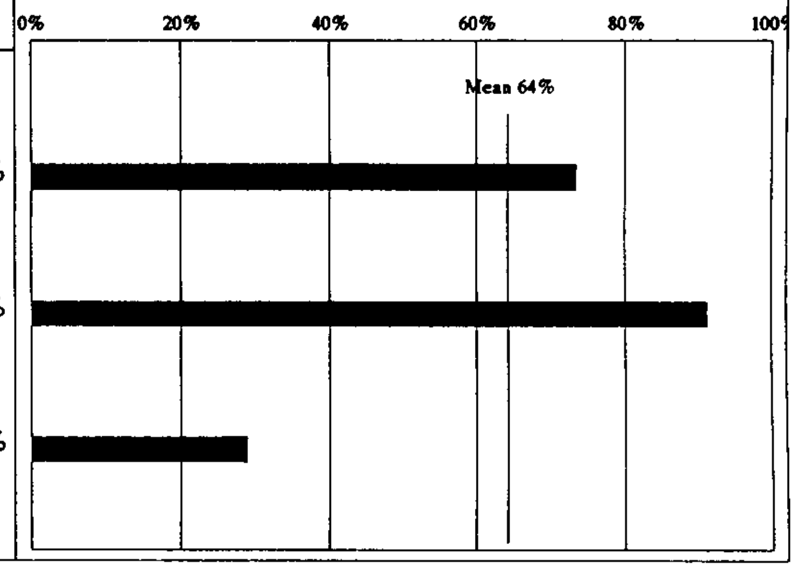
Responsibilities Supplier Involvment		Responses	Importance Total	Importance Average
	What importance do you attach to the following?			
6.c.1.	Mutual confidence between utility and supplier?	42	194	5
6.c.2.	Regular meetings between utility and supplier?	41	149	4
6.c.3.	Feed back to supplier of each operation; correct and incorrect?	41	122	3
6.c.4.	Feed back from supplier of every maloperation of a type of relay that occurred.	41	161	4
	Help from supplier for training of maintenance crews:			
6.c.5.	At the supplier?	39	117	3
6.c.6.	On site?	41	120	3
6.c.7.	Quick assistance on site possible when major incidents occur?	39	135	3
6.c.8.	Good response to resolve problems as they occur?	40	187	5
	Assurance that supplier will have or keep the			
6.c.9.	knowledge about the relays > 15 years?	41	178	4
6.c.10.	spare parts for relays > 15 years?	41	181	4



UTILITIES QUESTIONAIRE

SECTION 7

Maintenance		Responses	Yes Answers	Average (%)
	Do you have:			
7.a.1.	Written test procedures for each type of protection relay?	45	33	73%
7.a.2.	Test forms for people to fill in?	45	41	91%
7.a.3.	Automatic test procedures, carried out by computer test set?	45	13	29%



CIGRÉ WG 34−06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

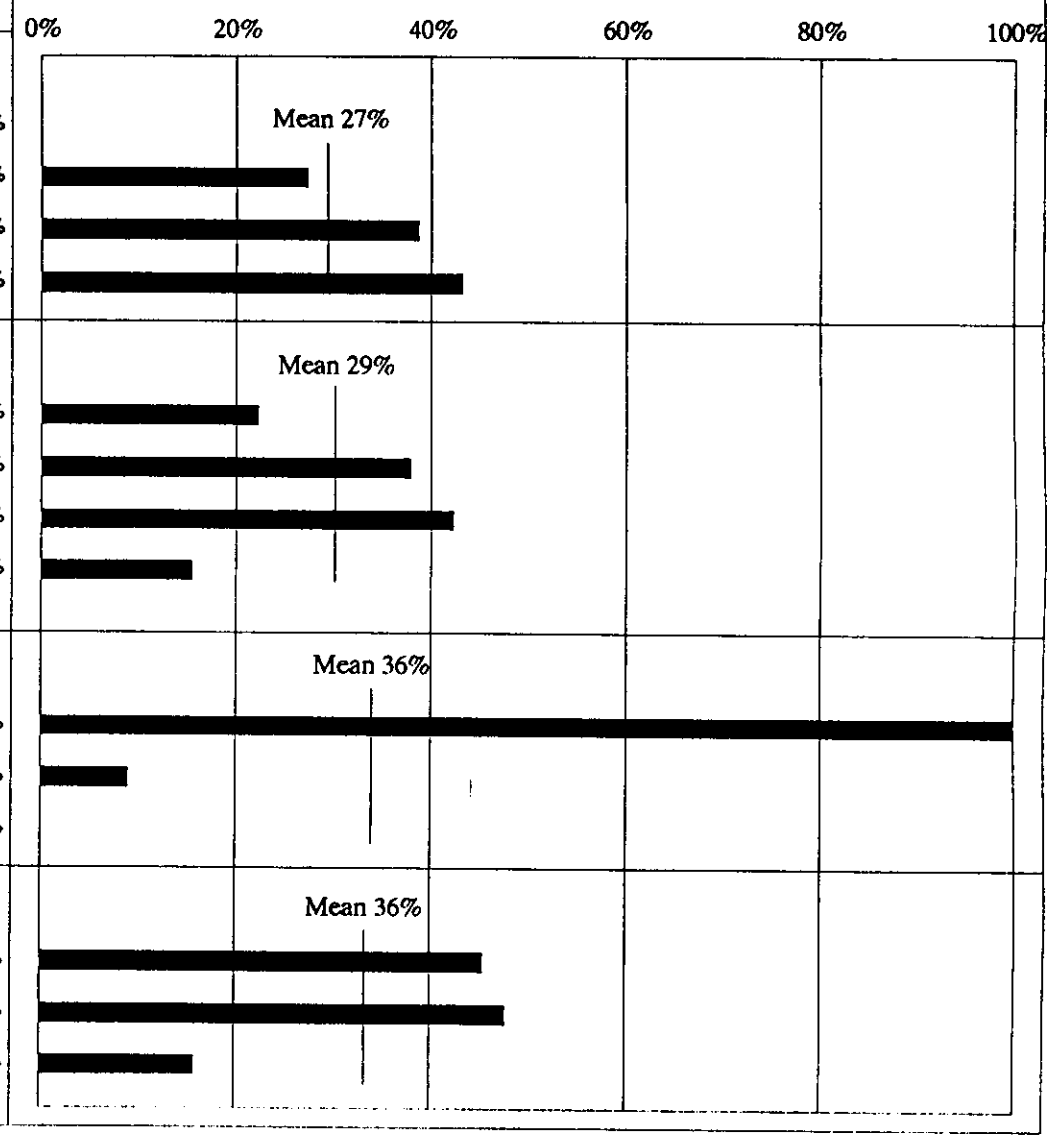
SECTION 7

Maintenance Periodic Maintenance		Responses	Yes Answers	Average (%)
	Do you carry out regular maintenance tests on:			
7.b.1.	Main protection relays?	45	42	93%
7.b.2.	Back−up protection?	45	40	89%
7.b.3.	Teleprotection?	45	31	69%
7.b.4.	Busbar protection?	45	36	80%
7.b.5.	Automatic switching equipment?	45	28	62%
7.b.6.	Clearing systems?	45	15	33%
7.b.7.	Circuit breaker failure?	45	35	78%
7.b.8.	Under−voltage and under/over frequency?	45	36	80%
7.c.	Are they the same tests as during commissioning of a known type of relay?	45	15	33%
7.d.	Do you maintain protection with the circuit on load?	45	24	53%

UTILITIES QUESTIONAIRE

SECTION 7

Maintenance		Responses	Yes Answers	Average (%)
	On average, do you do regular maintenance of protection at intervals of:			
7.e.1.	< 1 year?	44	0	0%
7.e.2.	1 year?	44	12	27%
7.e.3.	2 years?	44	17	39%
7.e.4.	> 2 years?	44	19	43%
	Do you do, or intend to do, maintenance less often:			
7.f.1.	On systems with 2 main protections than on those with 1?	45	10	22%
7.f.2.	On relays with self checking than on those without?	45	17	38%
7.f.3.	On relays with automatic self testing than on those without?	45	19	42%
7.f.4.	On static relays than on electromechanical relays?	45	7	16%
	Do you plan a special test on a relay after incorrect operation:			
7.g.1.	By utility?	45	45	100%
7.g.2.	By supplier?	45	4	9%
7.g.3.	none?	45	0	0%
	What do you forsee in the planning of maintenance for the following 5 to 10 years?			
7.h.1.	Same sequence?	44	20	45%
7.h.2.	Less often? (based on experience)	44	21	48%
7.h.3.	More often? (relays becoming older)	44	7	16%

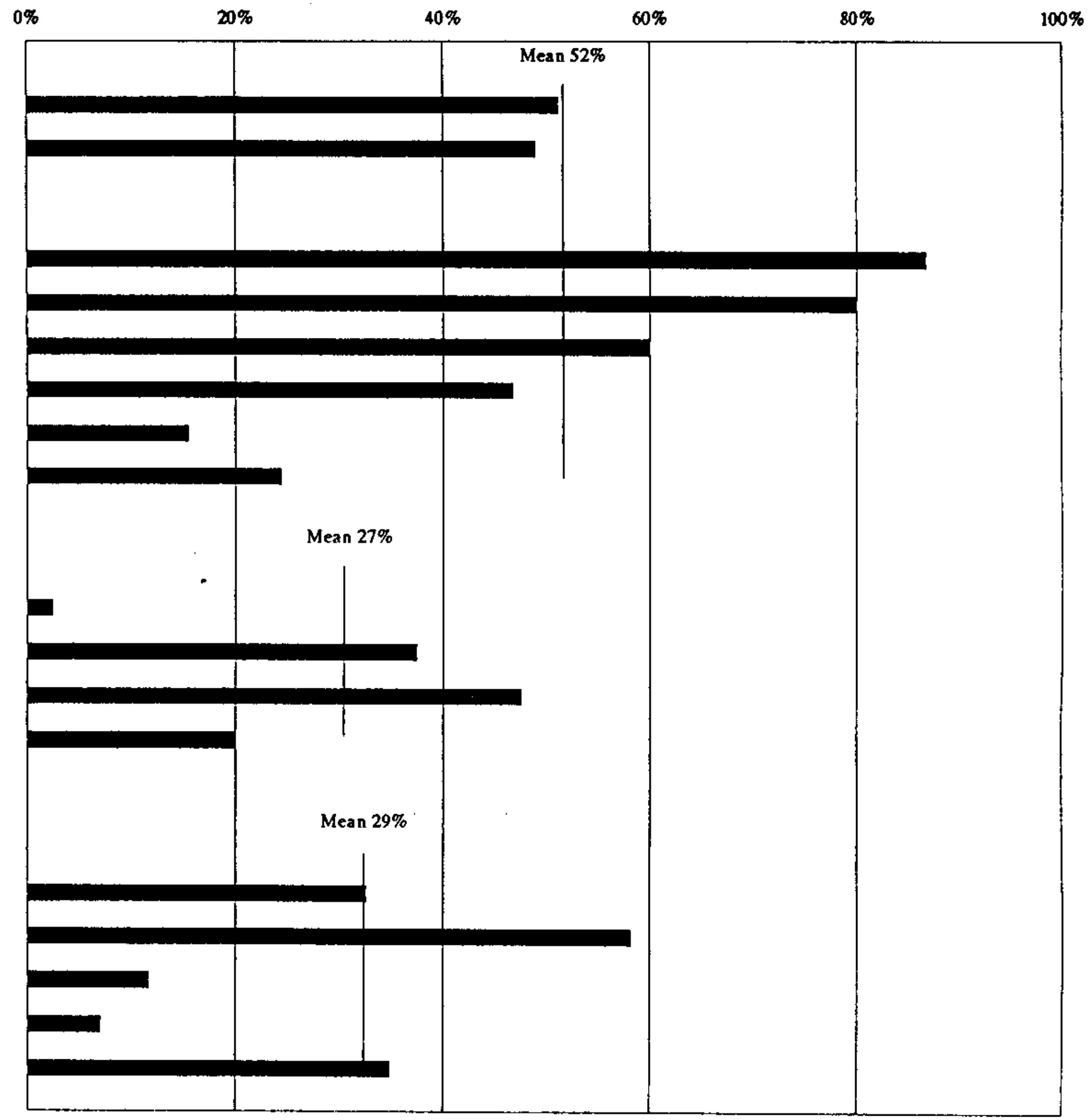


CIGRÉ WG 34-06 Maintenance and Management of Protection Systems

UTILITIES QUESTIONAIRE

SECTION 8

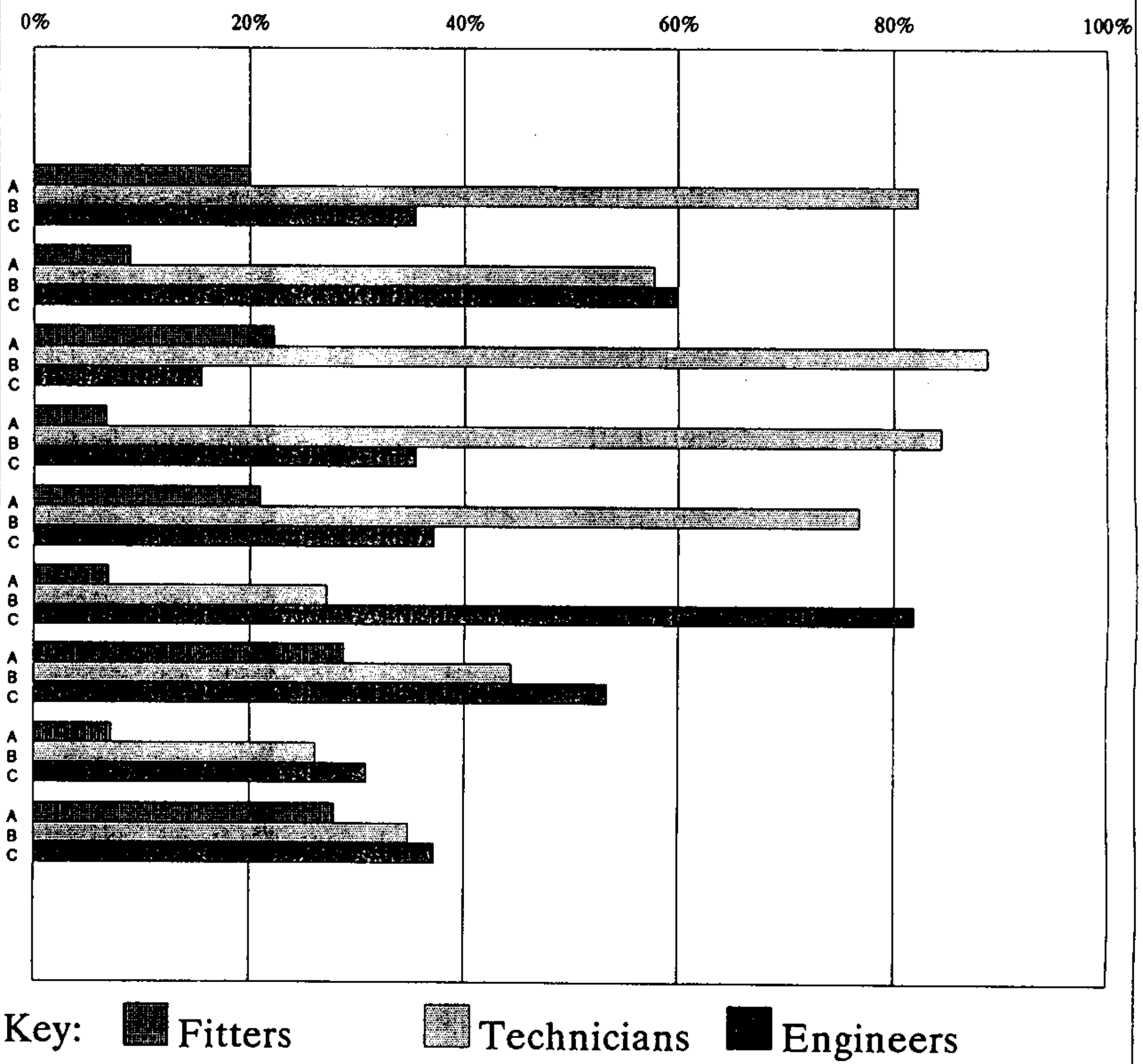
Spares		Responses	Yes Answers	Average (%)
	Do you hold spare parts for all relays in:			
8.a.1.	Centralised storage?	45	23	51%
8.a.2.	Decentralised storage?	45	22	49%
	Do you keep:			
8.a.3.	Spare relays?	45	39	87%
8.a.4.	Spare printed circuit cards?	45	36	80%
8.a.5	Spare devices other than relays?	45	27	60%
8.a.6	Spare components?	45	21	47%
8.a.7.	Repair kit for each type of relay?	45	7	16%
8.a.8.	Manufactures recomended levels of spares?	45	11	24%
	For how many years after last commissioning are spare parts available from the supplier?			
8.b.1.	< 5 years	40	1	3%
8.b.2.	5 – 10 years	40	15	38%
8.b.3.	10 – 15 years	40	19	48%
8.b.4.	> 15 years	40	8	20%
	What average turn-around would you expect from the manufacturer if you return a faulty relay?			
8.c.1.	< 1 month	43	14	33%
8.c.2.	1 – 6 months	43	25	58%
8.c.3.	6 months – 1 year	43	5	12%
8.c.4.	> 1 year	43	3	7%
8.c.5.	Do you think this is satisfactory?	43	15	35%



UTILITIES QUESTIONAIRE

SECTION 9

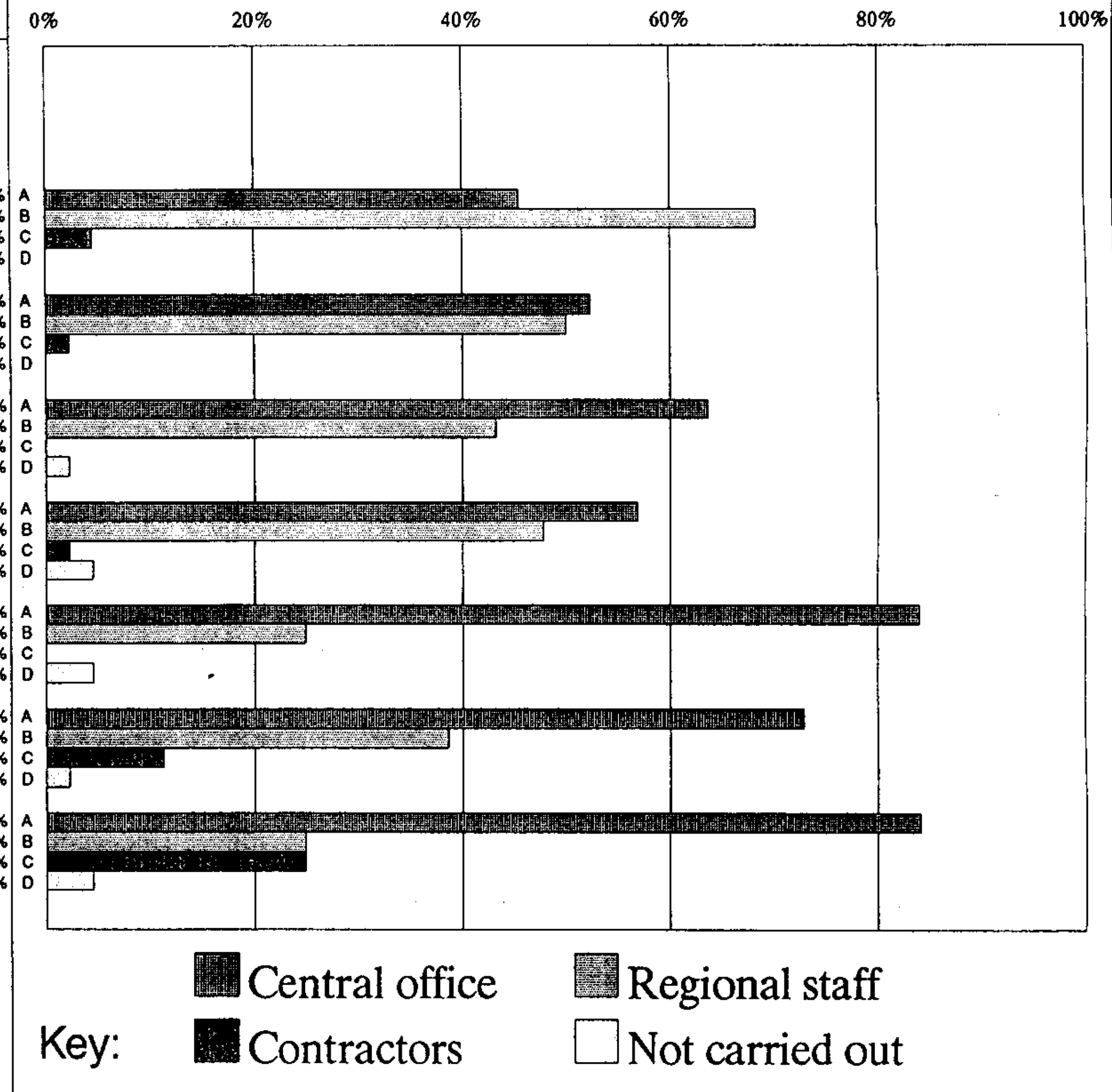
Personnel		Responses	Yes Answers	Average (%)	
	What skill levels are employed for the following functions where: A = electrical fitter B = electrical / electronic technician C = electrical engineer				
9.1.	Maintenance of protections on site, including any adjustments that are required	45	9	20%	A
		45	37	82%	B
		45	16	36%	C
9.2.	Commissioning of new or modified protection	45	4	9%	A
		45	26	58%	B
		45	27	60%	C
9.3.	Repair or modification of faulty electromechanical relays	45	10	22%	A
		45	40	89%	B
		45	7	16%	C
9.4.	Repair or modification of faulty electronic relays	45	3	7%	A
		45	38	84%	B
		45	16	36%	C
9.5.	Data entry into information systems	43	9	21%	A
		43	33	77%	B
		43	16	37%	C
9.6.	Analysis of data in information systems	44	3	7%	A
		44	12	27%	B
		44	36	82%	C
9.7.	Are you experiencing recruitment and retention difficulties in these skill areas?	45	13	29%	A
		45	20	44%	B
		45	24	53%	C
9.9	Do you expect the number of people employed in these skill levels to increase in the future due to the introduction of digital relays?	42	3	7%	A
		42	11	26%	B
		42	13	31%	C
9.8.	Approximately how many people are employed at these skill levels in your company?	42	1174	28	A
		42	1466	35	B
		42	1568	37	C



UTILITIES QUESTIONAIRE

SECTION 9

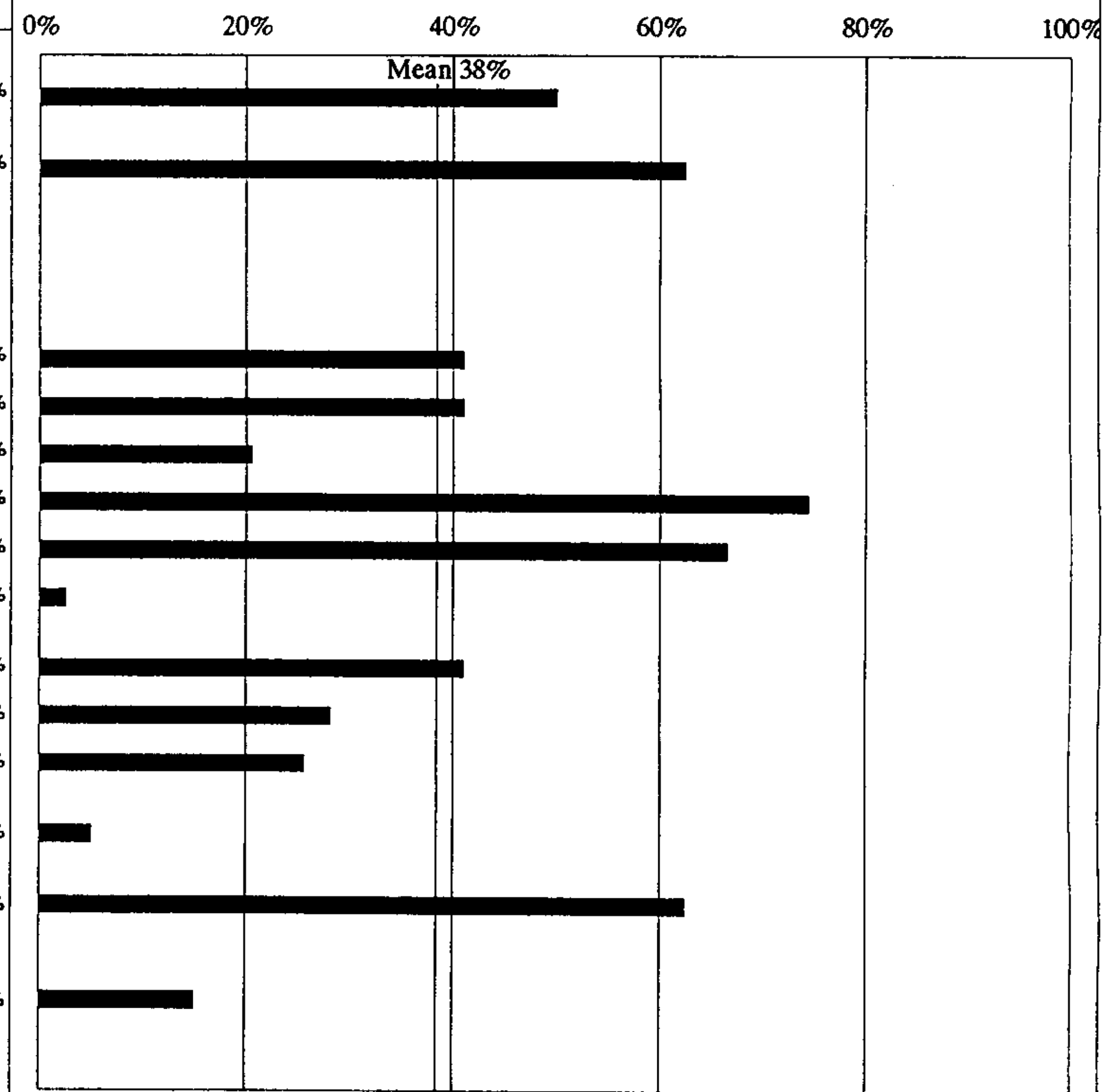
Personnel		Responses	Yes Answers	Average (%)	
	Are the following function carried out by: A = Central office? B = Regional staff? C = Contractors? D = Not carried out?				
9.10.	Maintenance of grid system protection	44	20	45%	A
		44	30	68%	B
		44	2	5%	C
		44	0	0%	D
9.11.	Maintenance of sophisticated protection e.g. digital teleprotection	44	23	52%	A
		44	22	50%	B
		44	1	2%	C
		44	0	0%	D
9.12.	Planning of maintenance	44	28	64%	A
		44	19	43%	B
		44	0	0%	C
		44	1	2%	D
9.13.	Data entry into information system	44	25	57%	A
		44	21	48%	B
		44	1	2%	C
		44	2	5%	D
9.14.	Analysis of data in information system	44	37	84%	A
		44	11	25%	B
		44	0	0%	C
		44	2	5%	D
9.15.	Training of maintenance staff	44	32	73%	A
		44	17	39%	B
		44	5	11%	C
		44	1	2%	D
9.16.	Training for the introduction of new types of protection	44	37	84%	A
		44	11	25%	B
		44	11	25%	C
		44	2	5%	D



UTILITIES QUESTIONAIRE

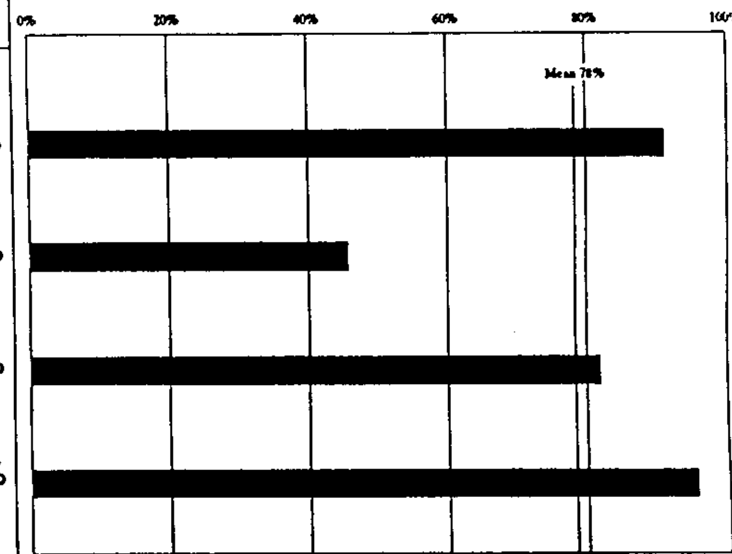
SECTION 10

Life Cycle Cost		Responses	Yes Answers	Average (%)
10.1.	Do you intend to reduce life cycle cost of protection in particlar in the near future?	40	20	50%
10.2.	Do you intend to control life cycle cost in order to make better decisions in matters of protection?	40	25	63%
	Indicate the top 3 fields in which you want to gain in life cycle cost reduction in the future:			
	a) equipment			
10.3.1.	initial cost of relay	39	16	41%
10.3.2.	installation and commissioning	39	16	41%
10.3.3.	life time	39	8	21%
10.3.4.	maintenance time	39	29	74%
10.3.5.	self check	39	26	67%
10.3.6.	any other	39	1	3%
	b) personnel			
10.3.7.	training	39	16	41%
10.3.8.	number	39	11	28%
10.3.9.	employment of technicians	39	10	26%
10.3.10.	c) any other	39	2	5%
10.4.	Do you expect the introduction of digital techniques will help to reduce life cycle costs?	40	25	63%
10.5.	Please specify in more detail if required the company policy concerning cost reduction in protection:	40	6	15%



MANUFACTURERS QUESTIONAIRE

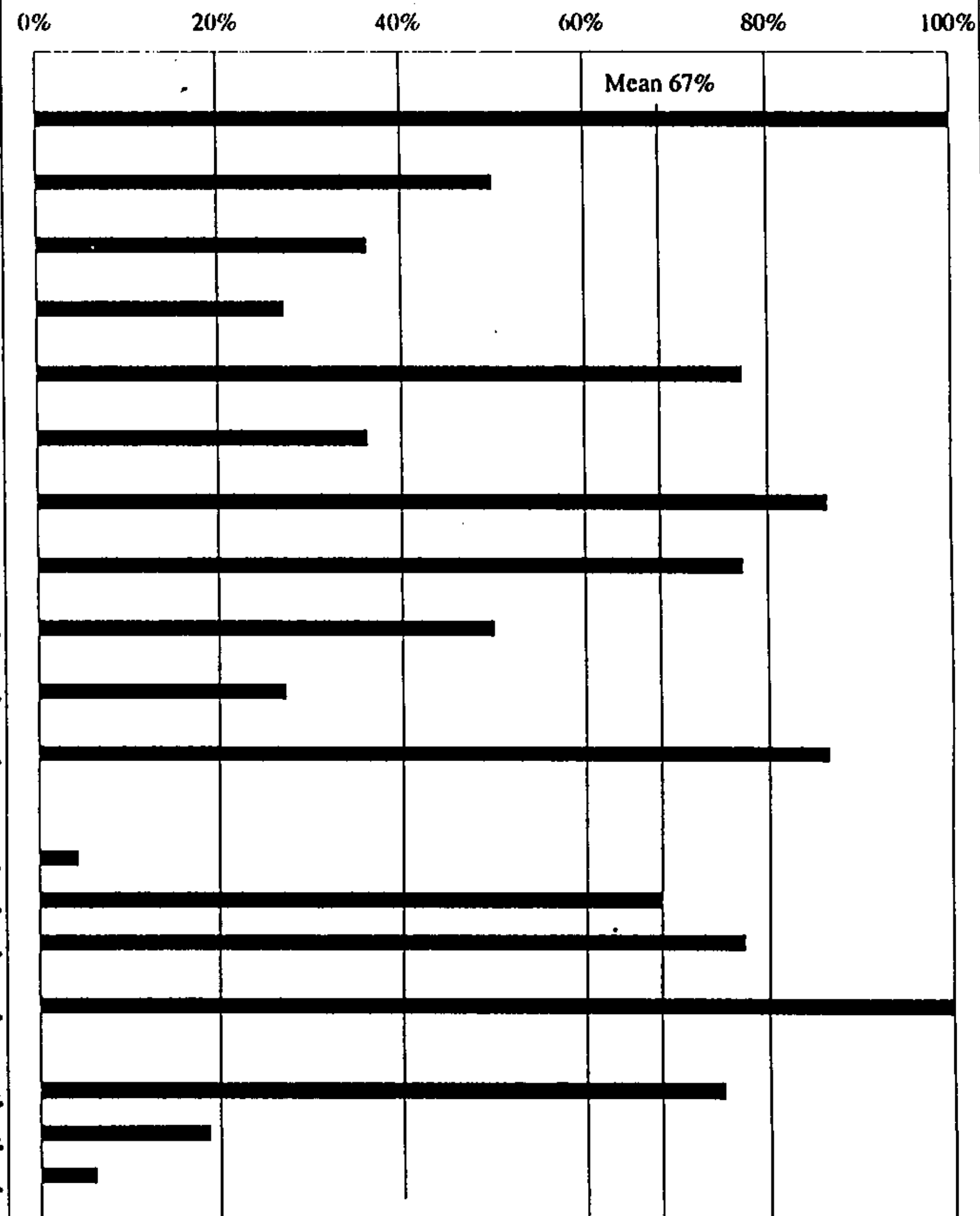
Development Of Protection		Responses	Yes Answers	Average (%)
2a	Do you have an input from utilities when developing a new protection relay?	22	20	91%
2b	Do you involve utility personnel in type testing?	22	10	45%
2c	Do you seek utility or other third–party approval?	22	18	82%
2d	Do you subject new protection relays to system trails with utilities?	22	21	95%



CIGRÉ WG 34-06 Maintenance and Management of Protection Systems

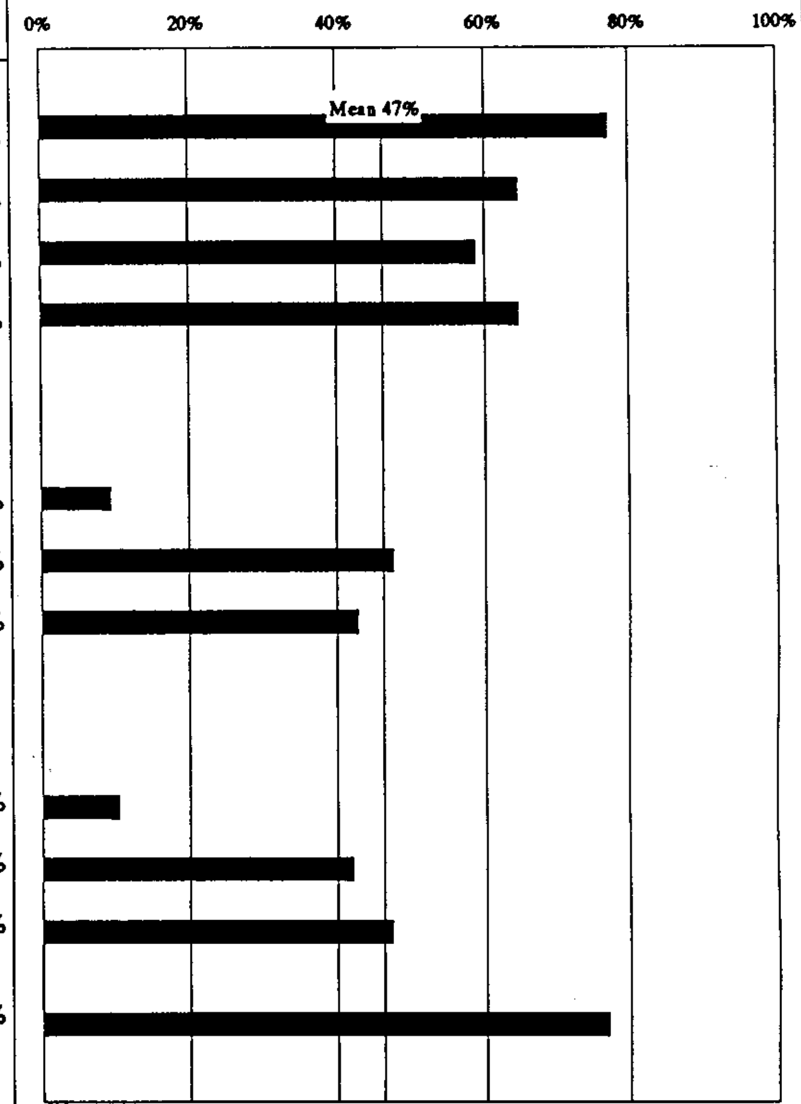
MANUFACTURERS QUESTIONAIRE

Maintenance		Responses	Yes Answers	Average (%)
	What kind of information do you supply to utilities:			
3a	Do you give maintenance instructions for the relays?	22	22	100%
3b	Does the maintenance instructions include a recommended test interval?	22	11	50%
3c	Do you recommend different test intervals for different types of relay?	22	8	36%
3d	Do you recommend different test intervals for relays with self checking features?	22	6	27%
3e	Do you recommend what test equipment to use?	22	17	77%
3f	Do you provide programs for use of automatic test equipment?	22	8	36%
3g	Do you co-operate with utilities concerning maintenance recommendations?	22	19	86%
3h	Do utilities return relays for repair after maloperation?	22	17	77%
3i	Do you always return the same relay to the utility after repair?	22	11	50%
3j	Do you return another relay in exchange?	22	6	27%
3k	Do you give the utility a report of the failure and measures taken?	22	19	86%
	Do you recommend that utilities repair relays themselves by			
3.l.1.	- replacing individual components?	22	1	4%
3.l.2.	- replacing cards?	22	15	68%
3.m.	Do you have a target period within which you return or replace a faulty relay or card?	22	17	77%
3.m.1.	If so, what is it (in weeks)	17	52.5	309%
	If so, what is your success rate?			
3.m.2.	80 - 100%	16	12	75%
3.m.3.	50 - 80%	16	3	19%
3.m.4.	< 50%	16	1	6%



MANUFACTURERS QUESTIONAIRE

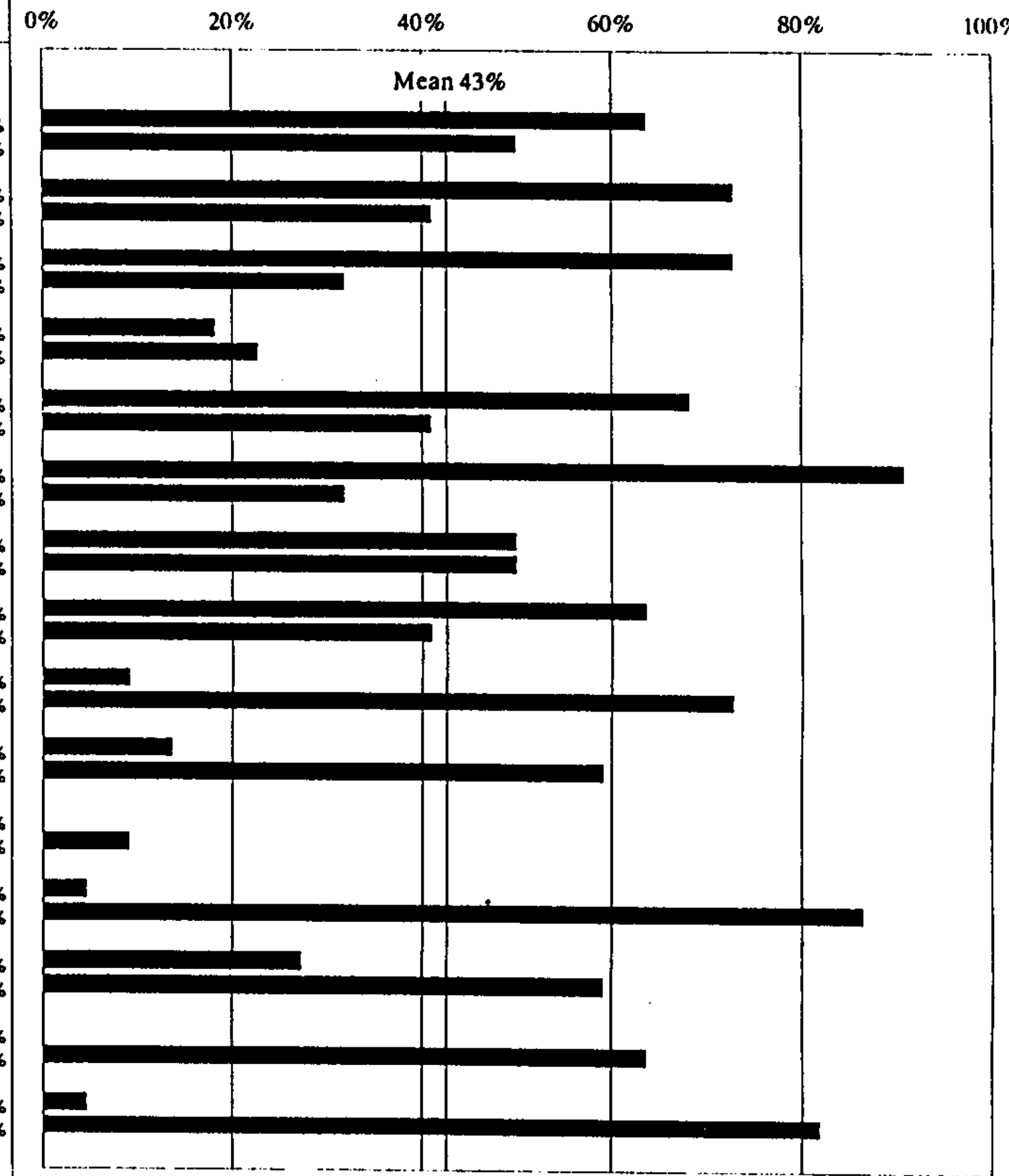
Spare Parts		Responses	Yes Answers	Average (%)
4a	Do you hold spare parts on behalf of your customers?	22	17	77%
4.a.1.	components	17	11	65%
4.a.2.	cards	17	10	59%
4.a.3.	relays	17	11	65%
4b	For how long will spare parts be available after production has ceased?			
4.b.1.	< 5 years	21	2	10%
4.b.2.	5 – 10 years	21	10	48%
4.b.3.	> 10 years	21	9	43%
4c	For how long after incorporation into a protection will you support software program?			
4.c.1.	< 5 years	19	2	11%
4.c.2.	5 – 10 years	19	8	42%
4.c.3.	> 10 years	19	9	47%
4d	Do you recommend which spare parts your customers should hold?	22	17	77%



CIGRÉ WG 34–06 Maintenance and Management of Protection Systems

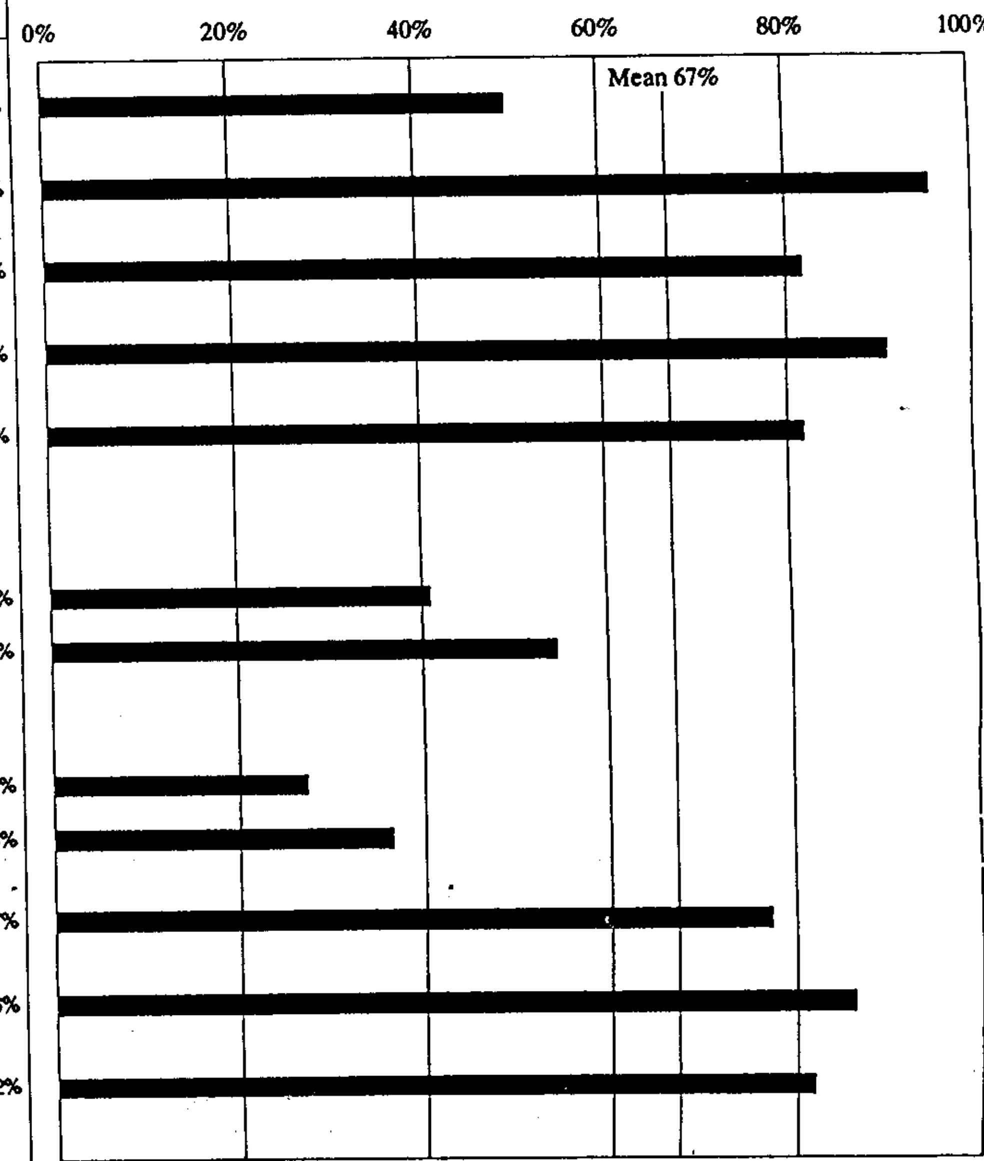
MANUFACTURERS QUESTIONAIRE

Information	a = with relays b = on request		Responses	Yes Answers	Average (%)
	What kind of information do you supply to utilities:				
5.a.1	Application guide?	a	22	14	64%
		b	22	11	50%
5.a.2.	Commissioning manual?	a	22	16	73%
		b	22	9	41%
5.a.3.	Maintenance manual?	a	22	16	73%
		b	22	7	32%
5.a.4.	Fault tracing chart?	a	22	4	18%
		b	22	5	23%
5.a.5.	Working principles?	a	22	15	68%
		b	22	9	41%
5.a.6.	External diagram of connections for the relay?	a	22	20	91%
		b	22	7	32%
5.a.7	Internal diagram of connections for the relay?	a	22	11	50%
		b	22	11	50%
5.a.8.	List of all cards?	a	22	14	64%
		b	22	9	41%
5.a.9.	List of all components?	a	22	2	9%
		b	22	16	73%
5.a.10.	Flow chart of software?	a	22	3	14%
		b	22	13	59%
5.a.11.	Source of software program?	a	22	0	0%
		b	22	2	9%
5.a.12.	Test reports (type test)?	a	22	1	5%
		b	22	19	86%
5.a.13.	Results of production tests?	a	22	6	27%
		b	22	13	59%
5.a.14.	Data needed for Life Cycle Cost analysis (e.g. probability of failure, lifetime)?	a	22	0	0%
		b	22	14	64%
5.a.15.	Quality plans?	a	22	1	5%
		b	22	18	82%



MANUFACTURERS QUESTIONAIRE

Information		Responses	Yes Answers	Average (%)
5b	Do you supply utilities with systematic information about every modification on the type of relay?	22	11	50%
5c	Do you keep a record of which utilities use your relays?	22	21	95%
5d	Do you keep a historical record of individual relays, i.e. customer returns?	22	18	82%
5e	Do you analyse customer returns for fault trends?	22	20	91%
5f	Do you give feed back to utilities of reported incorrect operations of a type of relay (i.e. type faults)?	22	18	82%
5g	Do you get statistics from utilities on the behaviour of your protection relays			
5.g.1.	performance during H.V. faults?	22	9	41%
5.g.2.	from maintenance?	22	12	55%
5h	If you get statistics, do you receive them			
5.h.1.	regularly?	22	6	27%
5.h.2.	on request?	22	8	36%
5i	Do you have regular meetings with utilities for exchange of information?	22	17	77%
5j	Do you offer training programmes for maintenance personnel?	22	19	86%
5k	Do you offer training programmes for protection specialists?	22	18	82%



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