

# **A SURVEY OF RELAYING TEST PRACTICES**

**A report to the  
Power System Relay Committee of  
the IEEE Power Engineering Society**

**prepared by working group I11**

## **Abstract**

The results of a survey of Relay Engineers concerning their practices for testing protective and other relays and their personnel requirements are presented.

## **Keywords**

Power Generating Protection, Relay Testing, Protective Relaying, Test Practices

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## 1. Introduction

In 1971, the IEEE Power System Relaying Committee reported the results of “A Survey of Relay Test Practices” [1], which reflected the responses of 125 electric utilities with a total of 1,157 generating stations, 5,096 transmission substations, and 17,849 distribution substations.

In 1991, the IEEE Power System Relaying Committee reported the results of “A Survey of Relay Test Practices” [2], which reflected the responses of 146 electric utilities with a total of 1,229 generating stations, 9,814 transmission substations and 26,680 distribution substations.

This present survey is based on 2001 data supplied by 79 electric utilities with an aggregate of 632 generating stations, 8,461 transmission substations and 12,499 distribution substations. Results of these surveys are compared to show significant changes in test practices and a trend toward longer test intervals.

The figures included in this report are named to identify with the Section of the survey from which the results are compiled.

## 2. Personnel Requirements

### 2.1 Personnel who Calibrate, Test and Maintain Relays

As a rule, the number of relay personnel is proportional to the size of the service area of the utility. Exceptions to this rule are those utilities having highly congested and heavily populated service areas which require significantly more relay personnel than do those utilities with an equivalent size service area that is less congested and not as heavily populated.

82 % of the respondents use specialists to calibrate, test and maintain their protective relays and associated equipment. 18 % of the respondents use non-dedicated personnel to perform relay testing in conjunction with other work such as circuit breaker, transformer, or battery maintenance. None of the respondents used any type of contract personnel for relay testing or maintenance.

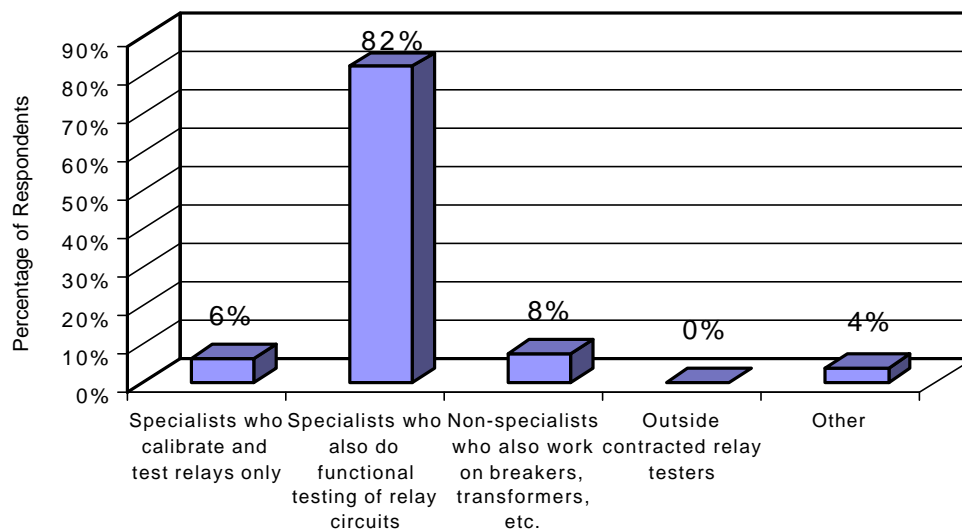


Figure 1: Personnel who Calibrate, Test and Maintain Relays

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## 2.2 Education Level Required

The survey indicated there is a broad mix of education levels employed as relay specialists across the industry. Figure 2 gives the percentage of individuals that fell into each education category.

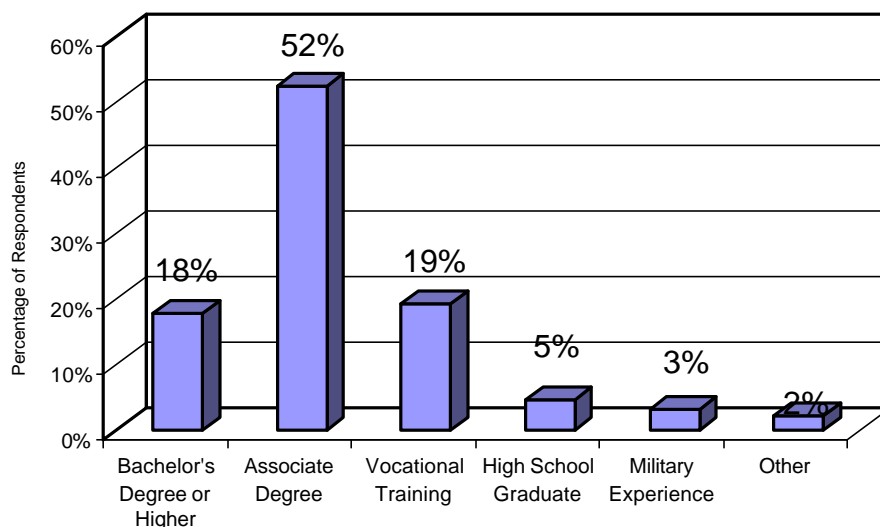


Figure 2: Education Level of Existing Relay Test Personnel

The survey also indicated this trend is not likely to change drastically due to current hiring practices. The only notable decline is in the hiring of personnel with Bachelor of Science degrees for the purpose of relay testing. Figure 3 gives a breakdown of the utilities' minimum education requirements.

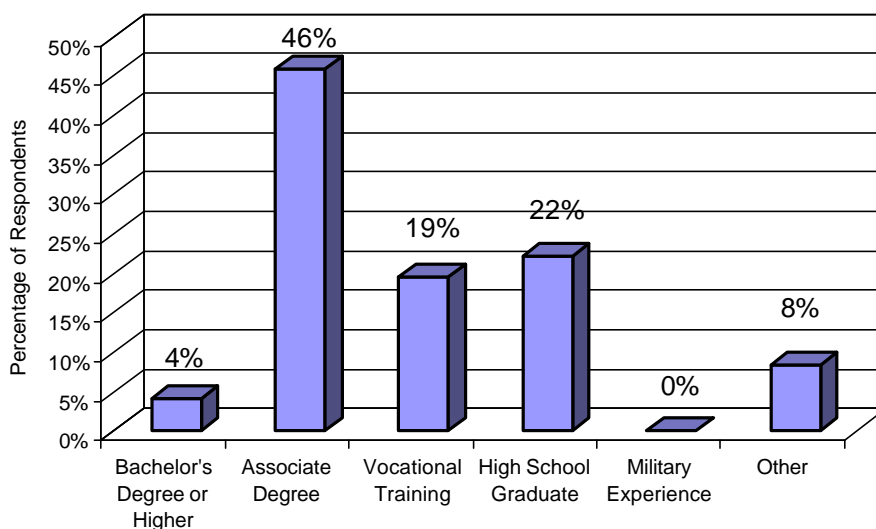


Figure 3: Level of Education Required for Newly-Employed Relay Test Personnel

## 2.3 Training Requirements

The survey indicated that the amount of relay-specific in-house training that relay employees receive on an annual basis varied considerably from utility to utility. Figure 4 shows that most relay test personnel receive fewer than 16 hours of relay training per year.

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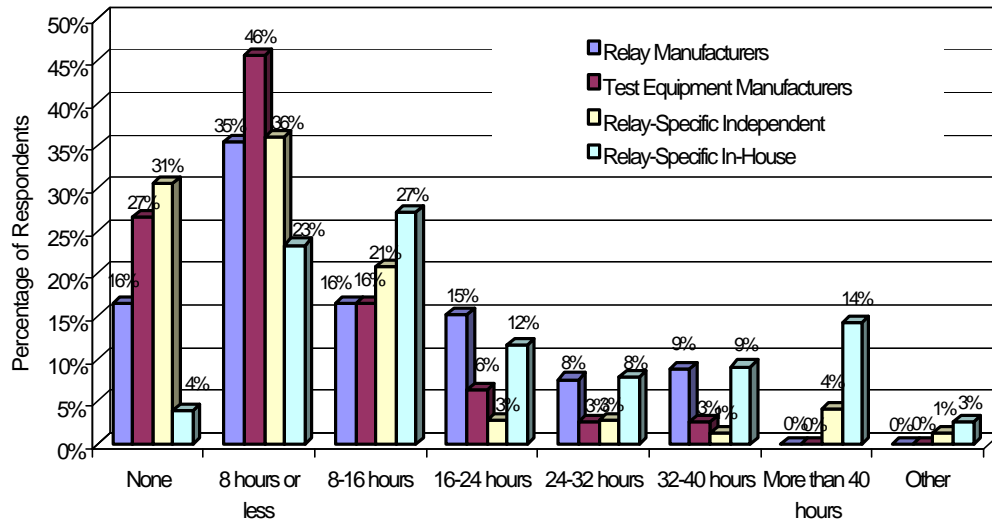


Figure 4: Training Hours per Test Personnel Each Year

Figure 5 shows that the working group foreman or test team group leader concept is widely used for training purposes by most utilities. The idea behind this type of training is that groups of personnel are assigned to work under the supervision of various knowledgeable senior relay foremen. Periodically, the various groups of technicians are rotated to work for another foreman until all the technicians have worked for all foremen. This type of training has many advantages for management.

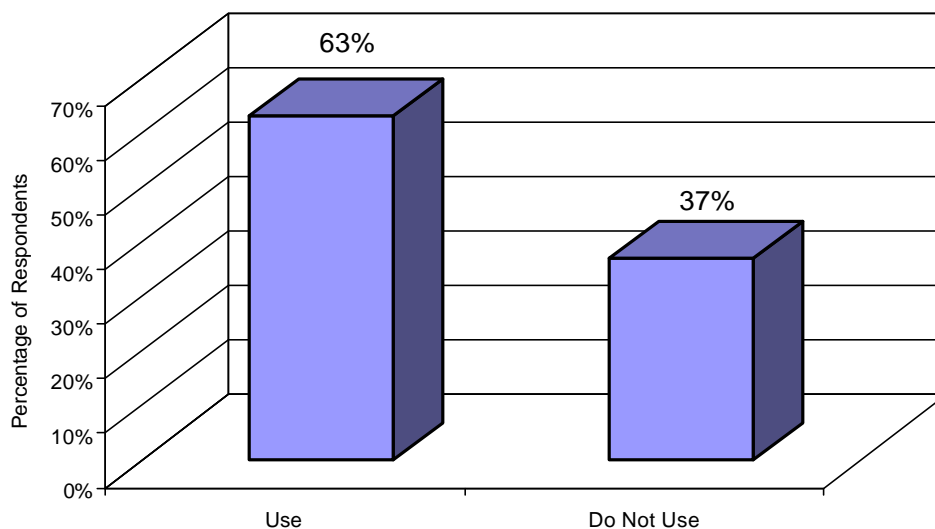


Figure 5: Utilities that Use a “Working Relay Foreman” or “Test Team Group Leader” to Train Relay Test Personnel

Significantly, 97 % of respondents utilize the same personnel to maintain both electromechanical relays and electronic relays, as indicated in Figure 6. Figure 7 indicates that most of the respondents require their personnel to have specialized electronics training, which is normally provided as on the job training.

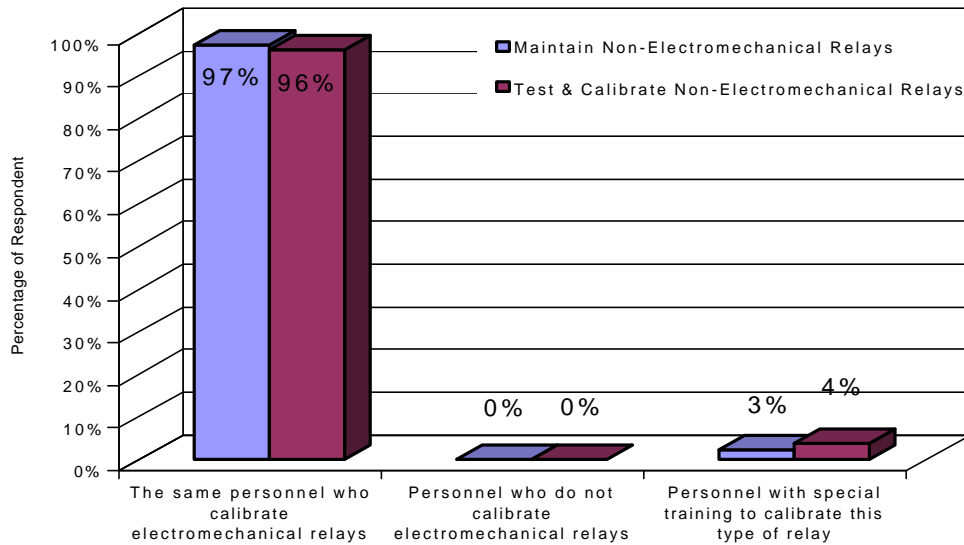


Figure 6: Personnel who Calibrate and Maintain Non-Electromechanical Relays

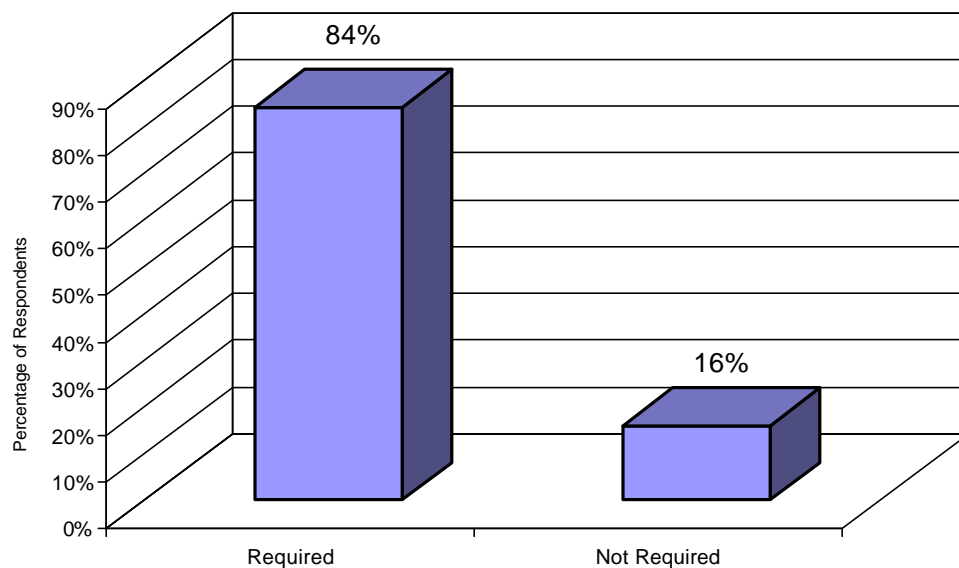


Figure 7: Utilities that Require Specialized Electronics Training for Personnel who Calibrate and/or Test Non-Electromechanical Relays

### 3. Relay Test Procedures

#### 3.1 Resources Used to Develop Relay Test Procedures

Figures 8 and 9 reflect the number of utilities who use In-House Procedures, Relay Manufacturers' Data and/or Equipment Manufacturers' Data for testing relays and their assessment of the value of each of these sources of data for test procedures.

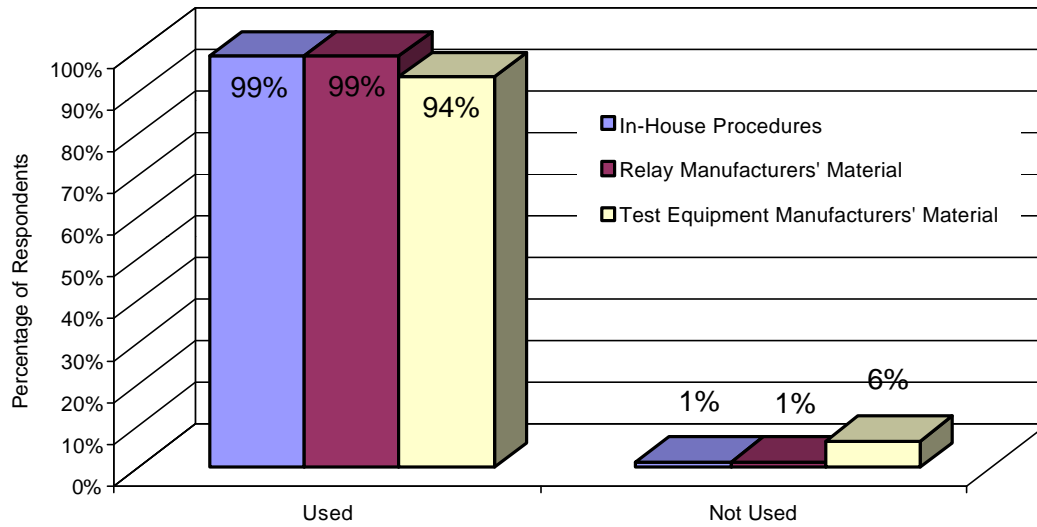


Figure 8: Resources Used to Develop Relay Test Procedures

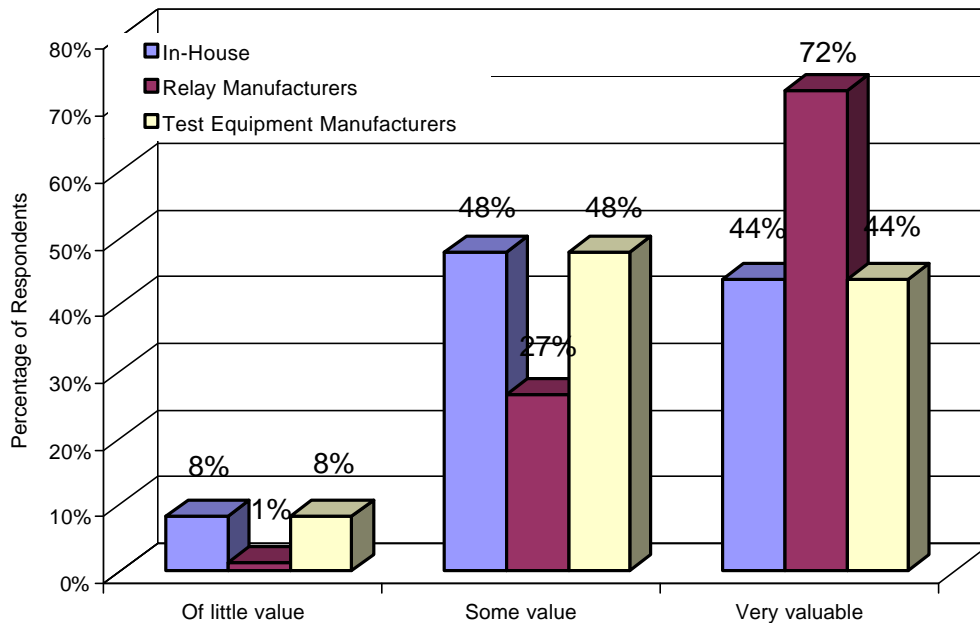


Figure 9: Value of In-House and Manufacturers' Materials in Developing Relay Test Procedures

All of the respondents use the Relay Manufacturers' materials as the basis for their testing, and many respondents also use test equipment manufacturers' materials to develop their test procedures.

### 3.2 How Normal Relay Testing is Accomplished

Figure 10 shows that 86 % of the respondents noted that they test relays using test plugs and secondary values, while 10 % cleared the circuit and tested the relay circuit with secondary values. Only 1 respondent stated that his utility tested relays using primary quantities.

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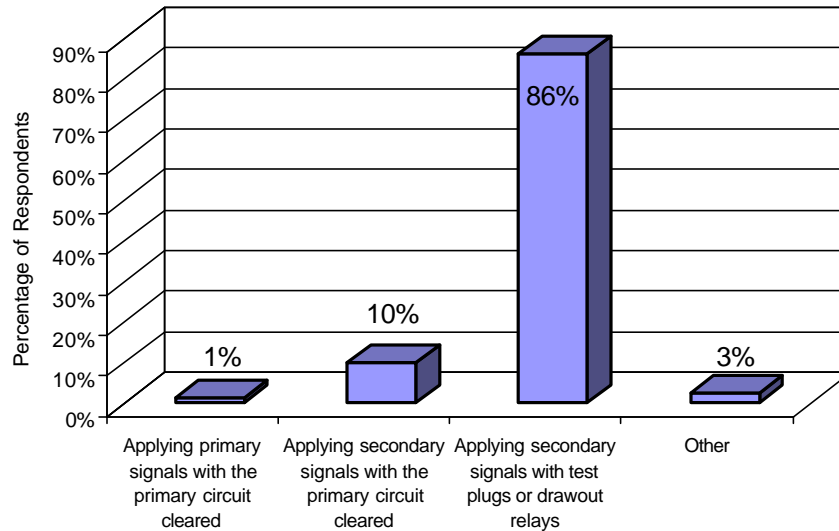


Figure 10: How Normal Field Relay Testing is Accomplished

Figure 11 details the percentage of respondents who test other items during routine relay testing. It should be noted that 28 % of those responding indicated that they perform all of the items shown in Figure 11 during the relay calibration procedure.

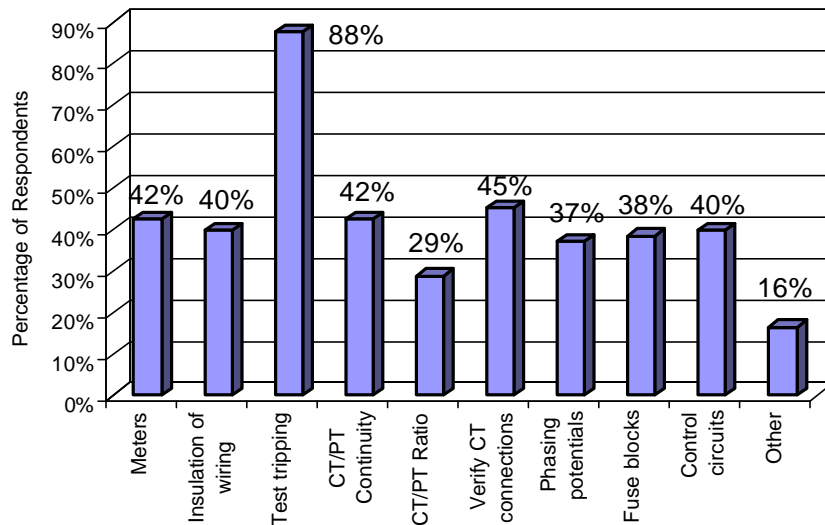


Figure 11: Associated Items Also Tested During Routine Relay Testing

Figure 12 reflects that when field testing of electromechanical relays indicate that repairs are needed, 95 % of the respondents rely on field personnel to do the repairs and only 5 % rely on the relay manufacturer. For non-electromechanical relays, 25 % of the utilities rely on their field personnel, 3 % on trained lab technicians and 72 % on the manufacturer. This is a major shift from the 1991 survey where 62 % relied on their field personnel, 12 % on trained lab technicians and only 26 % on the manufacturer.



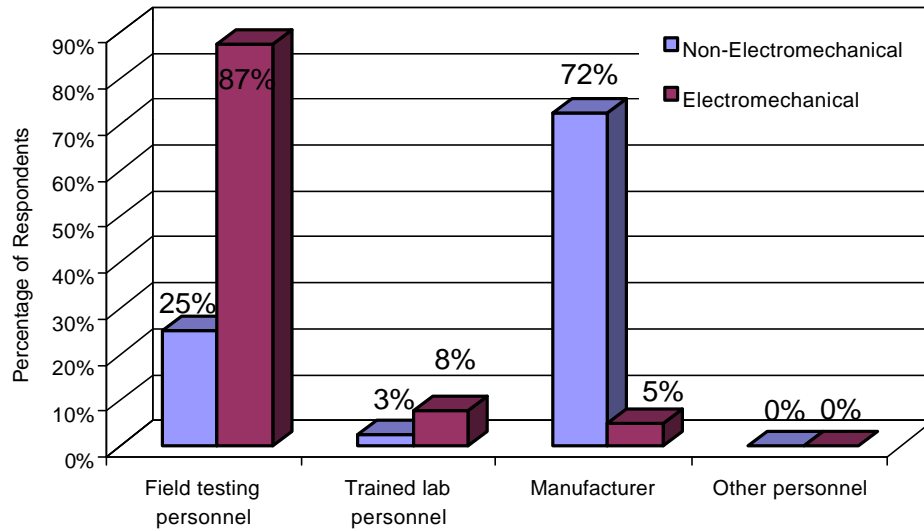


Figure 12: Personnel who Typically Repair Relays when Field Testing Determines that Repairs are Necessary

For use in testing non-electromechanical relays, Figure 13 indicates that 82 % of the respondents use test procedures developed especially for non-electromechanical relays.

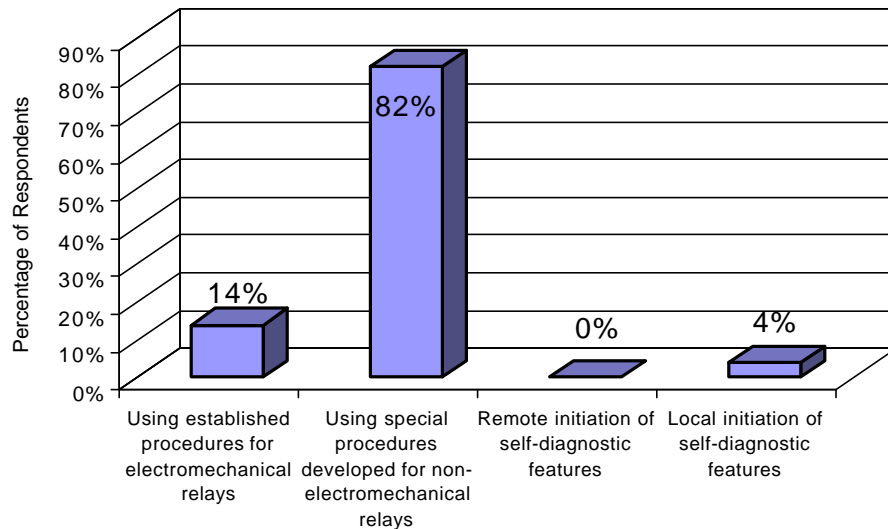


Figure 13: How Field Testing is Accomplished for Non-Electromechanical Relays

Figure 14 shows that performance of relays in service is evaluated for relay operations during faults by analysis of target, event recorder and oscillographic data by 46 % of the respondents, while 40 % rely on periodic relay test data. The 1991 survey revealed that 77 % evaluated performance of relays in service with operations during faults by analysis of target, event recorder, and oscillographic data and only 22 % relied on periodic relay test data. Note that the 1991 report stated that periodic relay testing seldom found problems with the relays.

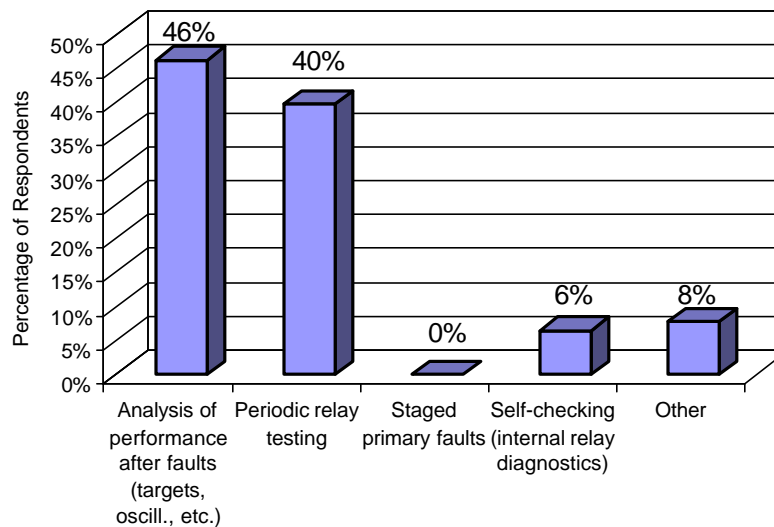


Figure 14: How In-Service Relay Performance is Determined

## 4. Allowable Relay Calibration Tolerances

### 4.1 Determination of Allowable Relay Tolerances

Figure 15 indicates that the majority of electric utilities surveyed use the protective relay “Manufacturers’ recommendations” (65 %), while “Knowledge and experience of the relay test personnel” represents a significant number of electric utilities that rely on personnel within their respective organizations (27 %) for relay tolerances.

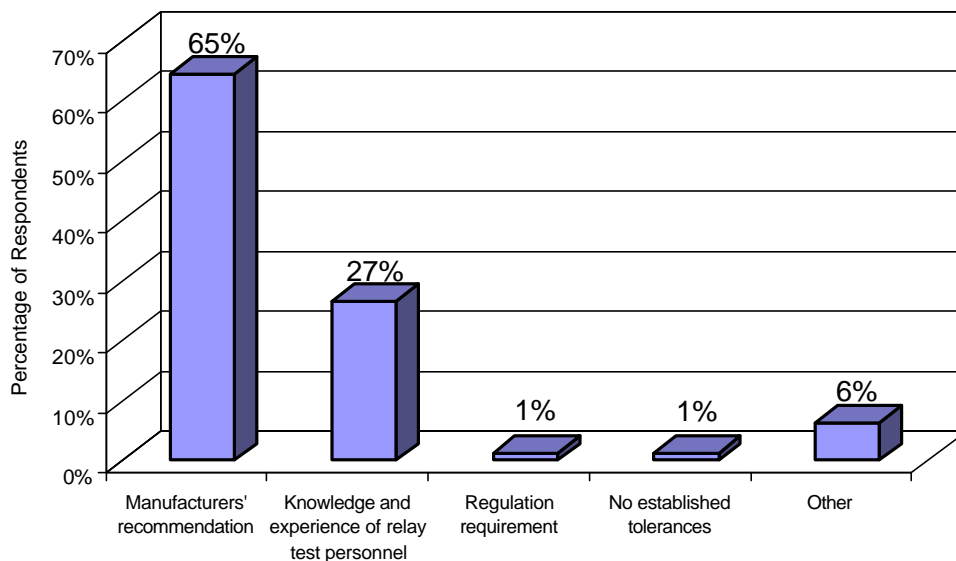


Figure 15: Determination of Allowable Relay Tolerances

The survey data indicates that a majority of relay manufacturers provide sufficient relay documentation that is acceptable to most engineers and technicians for maintenance and training purposes.

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The combined number of responses consisting of selections “No established tolerance”, Other means or practices”, and “No response to this question” (12.8 %) indicates that the determination of acceptable tolerances is completed by an internal or external organization and the survey may not have been transmitted to that group. This observation is verified by the additional comments provided indicating that this function is either contracted out or accomplished by engineering. Relaying engineers that responded to “other means or practices” provided information explaining that relay tolerances were set by established company guidelines.

## 4.2 Relay Applications that Require Tighter Tolerances

The purpose of this question is to determine if utilities establish tighter tolerances based on the individual relay characteristic, user application, function in a particular protective scheme or some other defined criteria rather than just the individual relay type or manufacturer involved.

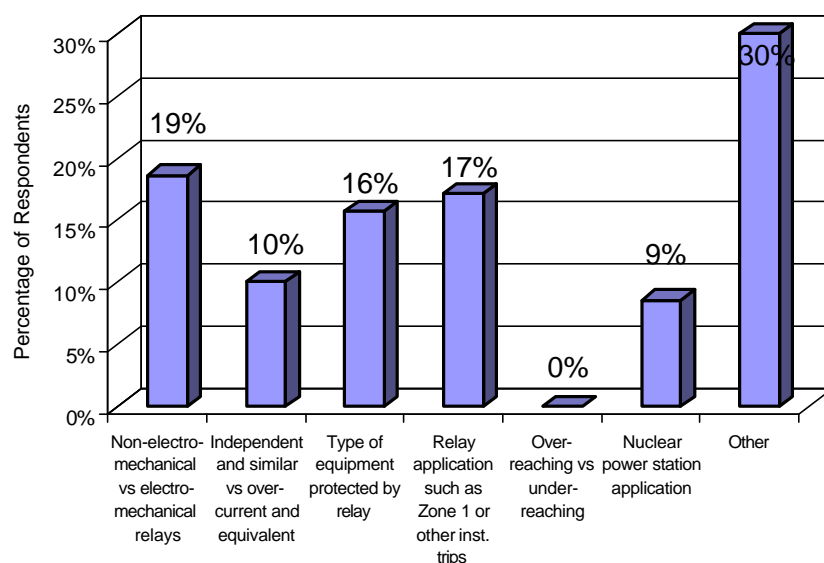


Figure 16: Relay Applications Requiring Tolerances Tighter than Those Normally Required

Although in the majority of cases non-electromechanical relays may have a more precisely defined pickup and dropout characteristic, only 19 % of the responses to the selection “Non-electromechanical versus electromechanical” felt that there is sufficient justification to warrant closer setting tolerances when using non-electromechanical relays.

User responses shown under the selection “Impedance versus overcurrent” (10 %) illustrates the concern of possible overreaching and the additional complexities associated with this type of relay. In general, the simple overcurrent relay has a larger allowable error setting tolerance due to its application.

The response under selection “Type of equipment being protected by the relay” (16 %) most likely denotes the concerns regarding major damage to critical types of power system apparatus and facilities.

It should be noted, however, that no distinction was made within the survey for the variety of more complex relays belonging to the overcurrent family of relays, such as those based on directional, negative sequence, or other defined supervising characteristics.

The survey responses shown under the selection “Relay application or other instantaneous trips” (17 %) regarding application such as Zone 1 or other instantaneous trip functions indicates that closer tolerances are used for these applications. Concerns regarding overreaching may be a major factor that directs testing philosophy for these applications.

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Selection “Overreaching versus underreaching (0 %) shows that an underreaching element is not more critical than an overreaching element.

Utilities with nuclear facilities obviously have eminent concerns regarding certain regulatory procedures and perceived outage effects. Tolerances are more closely reviewed than for companies without nuclear installations, or those having more rural type of distribution networks. This is reflected under selection “ Nuclear power station application” (9 %) of the utilities responding to this question.

A large number of responses (30 %) indicated other. This may indicate that all relays are calibrated with equal tolerances.

#### 4.3 Relay Applications for which Looser than Normal Tolerances are Permitted

The response to the survey question regarding the acceptability of looser tolerances for certain relay applications with respect to defined application is shown in Figure 17. Other than those responses under selection “Non-tripping relays”, it appears that from the selection “Other” (38 %) that, although no additional information was provided, many utilities may calibrate relays with equal tolerances.

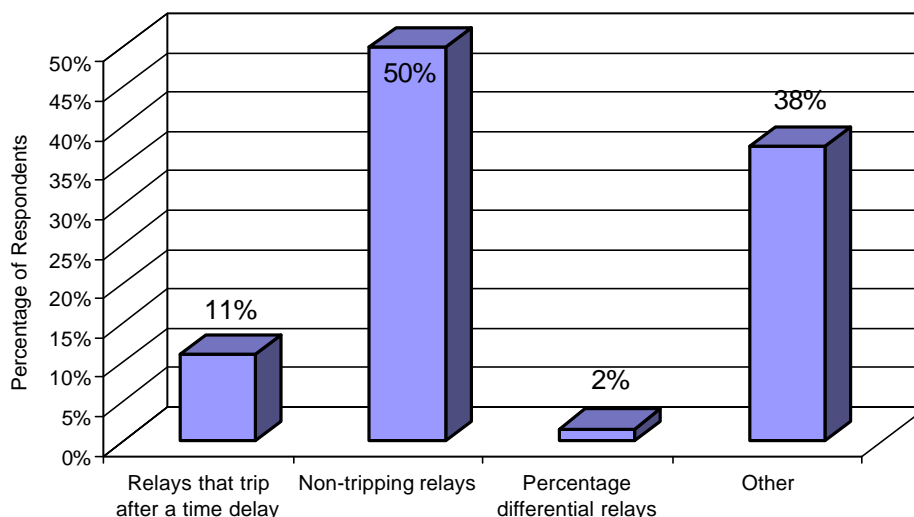


Figure 17: Relay Applications Requiring Tolerances Looser than Those Normally Required

A moderate percentage (11 %) of utilities indicated that “Relays that trip after a time delay” are not required to have a precise setting or other exacting factors that affect tolerances. The question does arise regarding the accuracy of the relay before tripping occurs if looser than normal tolerances acceptable with respect to its characteristic and those effects on the overall time delay.

The response under selection “Non-tripping relays” appears that a relative number of surveyed relay users (50 %) did agree that non-tripping relays are not required to have as tight a tolerance as those assigned to actual tripping purposes. Relays used for alarm applications, auto test, or circuit breaker reclosing are most likely part of this category.

#### 4.4 Documentation of Allowable Tolerances by the Relay Users

The response to the question of the survey regarding whether allowable relay tolerances are documented is provided in Figure 18 below.

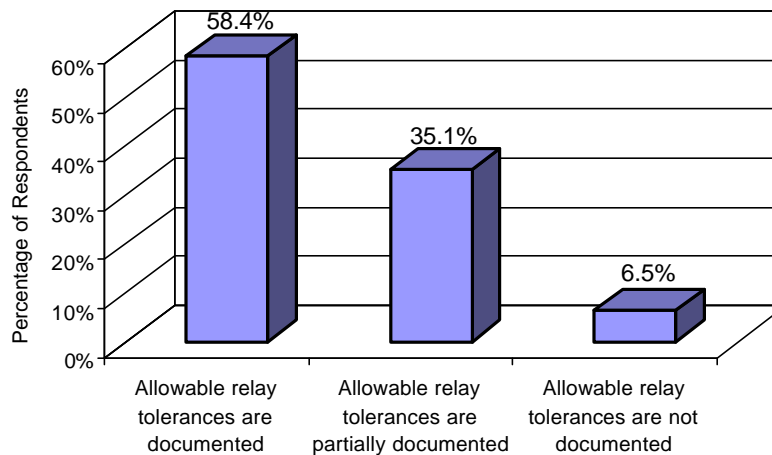


Figure 18: Documentation of Allowable Relay Tolerances

The combined selections “Allowable relay tolerances are documented” and “Allowable relay tolerances are partially documented” (93.5 %) reflect that the majority of the polled users do indeed compile documentation on relay tolerances.

## 5. Factors that Influence Relay Test Schedules

There has been a lot of pressure to increase the time period between relay test intervals. Increasing the test intervals obviously reduces direct testing costs. The probability that a failure will occur and exist undetected increases as the intervals go up. It is possible that relay crews will visit the less common relay systems so seldom that they will encounter delays while they have to relearn how to deal with them. This section of the survey was designed to investigate what are the most significant factors influencing selection of test intervals in the industry.

### 5.1 Basis for Test Intervals for Relays in T&D Substations

Figure 19 summarizes the respondents’ basis for selecting test intervals for relays protecting T&D substations. Nearly half of the respondents chose “Analysis of past results” and “Voltage level of circuit”. “Manpower capability or limitations” and “operations or misoperations” were also selected by a large number of respondents. It is interesting to note that all of the possible choices drew at least some selections, with “More complex relay types” selected by only two of the respondents.

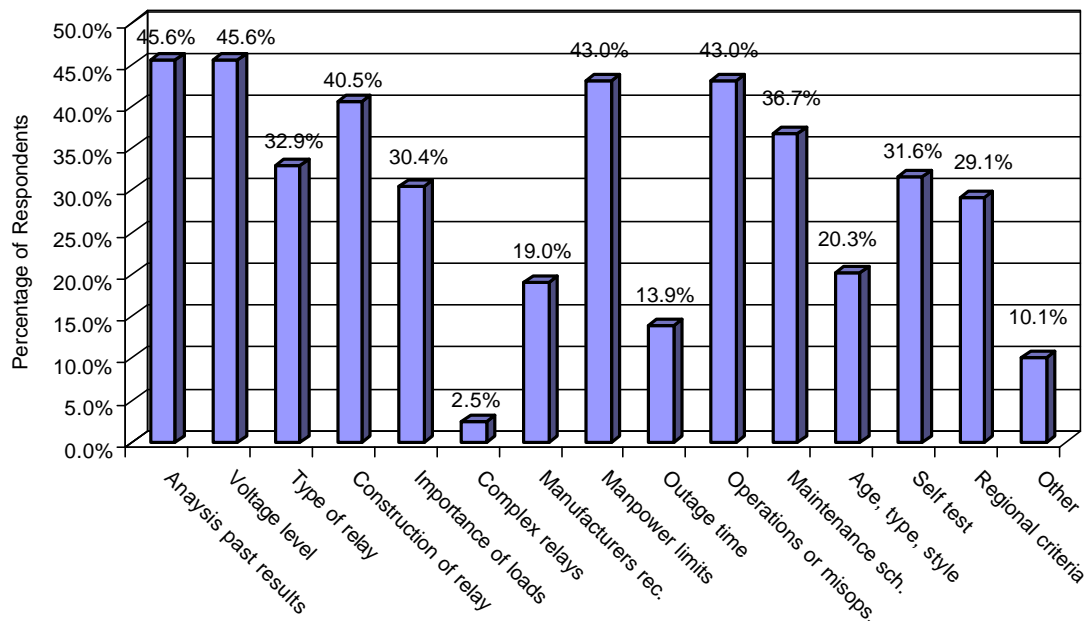


Figure 19: Basis for Test Intervals for Relays in T&D Substations

Figure 20 summarizes the most important factors in selecting the test intervals for T&D substation relays. While the results do not exactly correspond to those reflected in Figure 19, the two responses most frequently selected were again “Analysis of past results” and “Voltage level of circuit.”

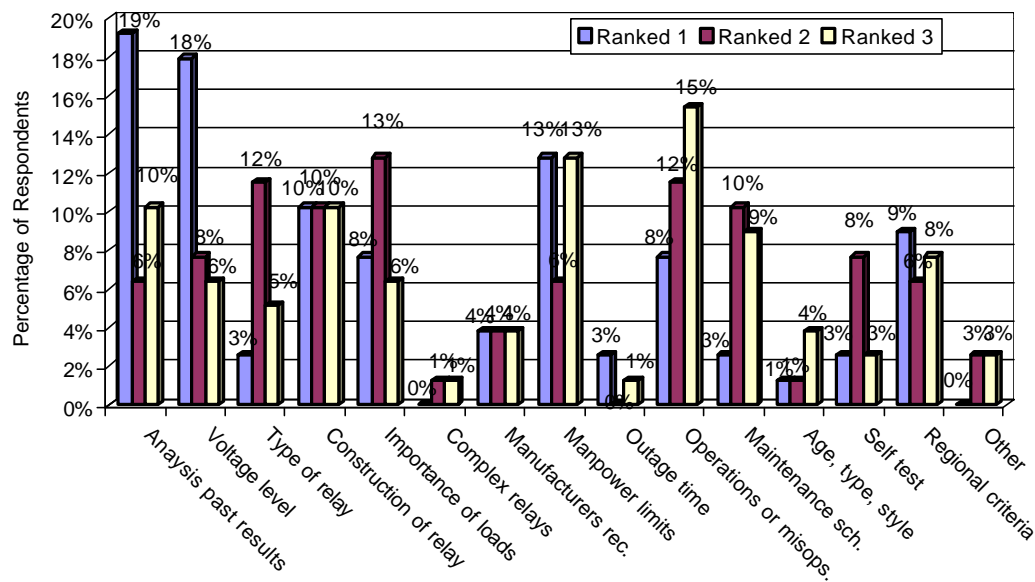


Figure 20: Most Important Factors in Selecting Test Intervals for Relays in T&D Substations

## 5.2 Rationale for Shorter Test Intervals

Figure 21 shows that shorter test intervals were selected for relays protecting higher (EHV) voltage systems by 56 % of the respondents. The particular type of relay being tested was also frequently chosen to be a basis for using shorter test intervals.

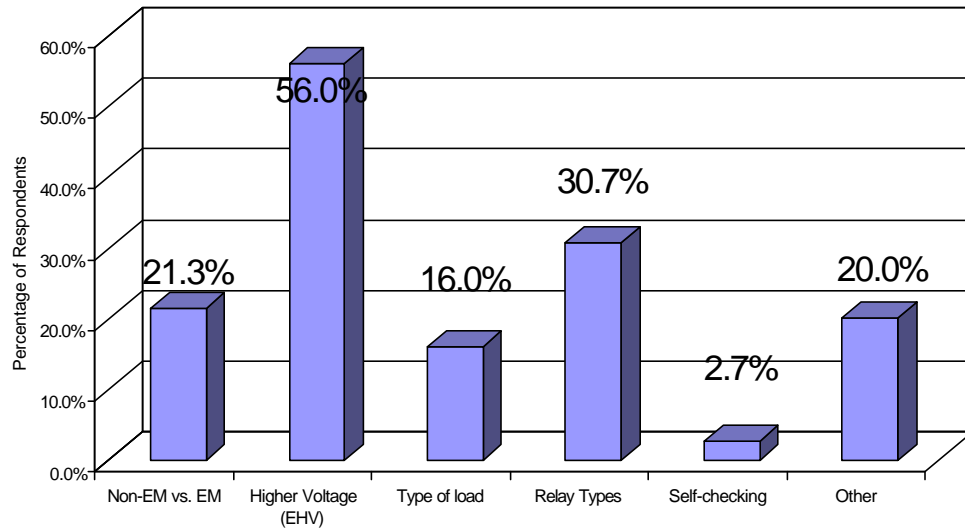


Figure 21: Reasons for Selection of Shorter Test Intervals for Relays in T&D Substations

## 5.3 Rationale for Longer Test Intervals

Figure 22 shows that 65 % of the respondents assign longer test intervals to T&D substation relays with self-checking algorithms. Again, as in the previous question, the particular type of relay was also a significant factor in choosing longer test intervals.

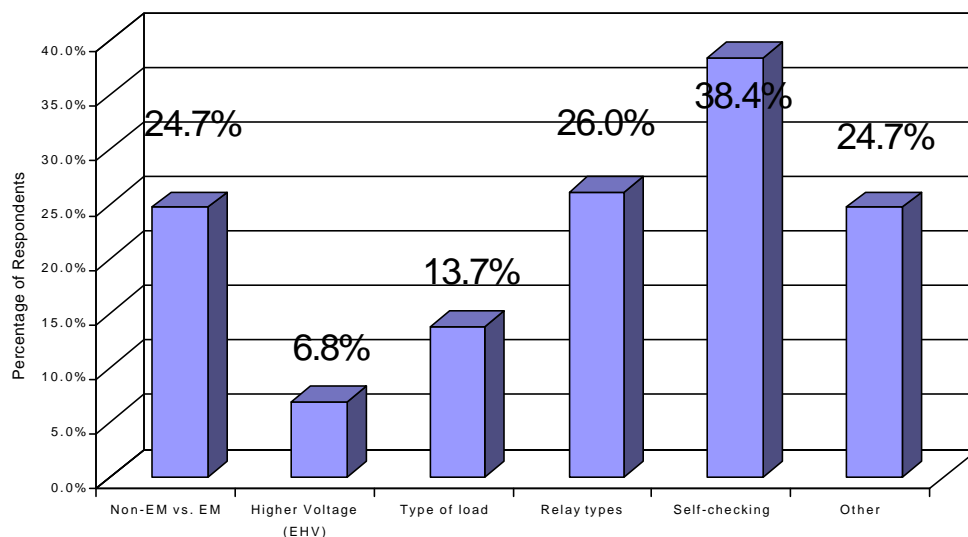


Figure 22: Reasons for Selection of Longer Test Intervals for Relays in T&D Substations

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## 5.4 Basis for Test Intervals for In-Plant Relays (Generator, Switchgear, etc.)

Figure 23 shows that a clear majority of respondents (almost 59 %) selected “Maintenance schedule of protected equipment” as a factor. The next two most frequently selected choices were “Operations and misoperations” and “Analysis of past results.” All of the possible choices drew at least some selections, with “More complex relay types” least frequently selected, consistent with the results collected for T&D substations.

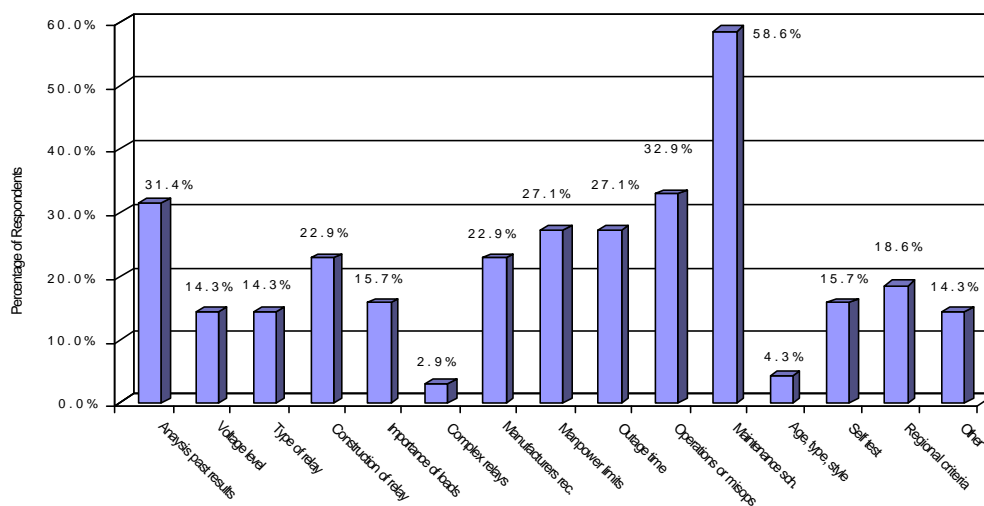


Figure 23: Basis for Test Intervals for In-Plant Relays

Figure 24 summarizes the most important factors for selection of test intervals for in-plant relays. The most frequently selected choice was “Maintenance schedule of protected equipment.” 12 % of the respondents ranked it as their most important factor.

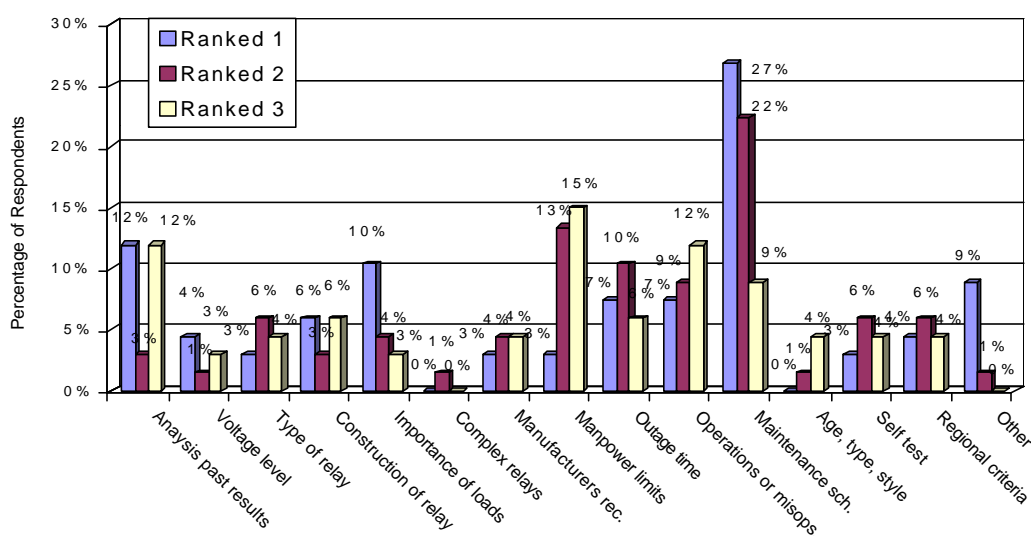


Figure 24: Most Important Factors in Selecting Test Intervals for In-Plant Relays

## 5.5 Test Intervals Actually Met in Practice

A majority of respondents, 65 %, reported that their scheduled relay test intervals are actually met in practice.

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## 6. Relay Test Intervals

### 6.1 Actual Relay Test Intervals Presently Used

The purpose of this section is to determine the relay test intervals for both electromechanical and non-electromechanical relays used in transmission, distribution, main generator, auxiliary bus, cogeneration and large industrial substations.

The complete responses are given by the bar charts shown in Figures 25 through 36.

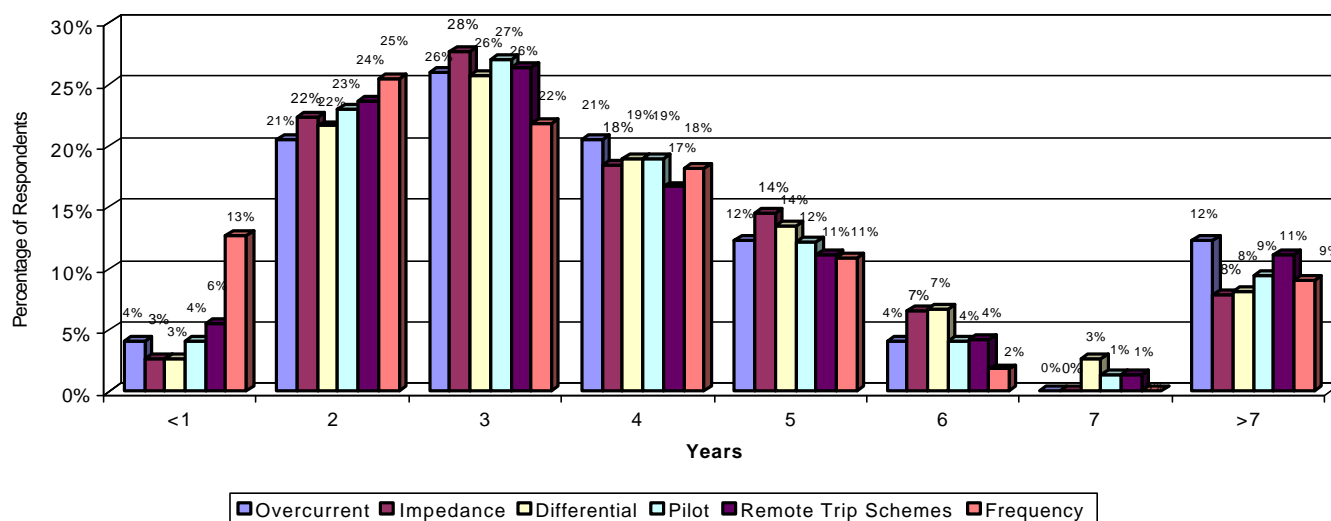


Figure 25: Time Intervals between Scheduled Relay Testing (years) - Electromechanical Relays on TRANSMISSION Circuits

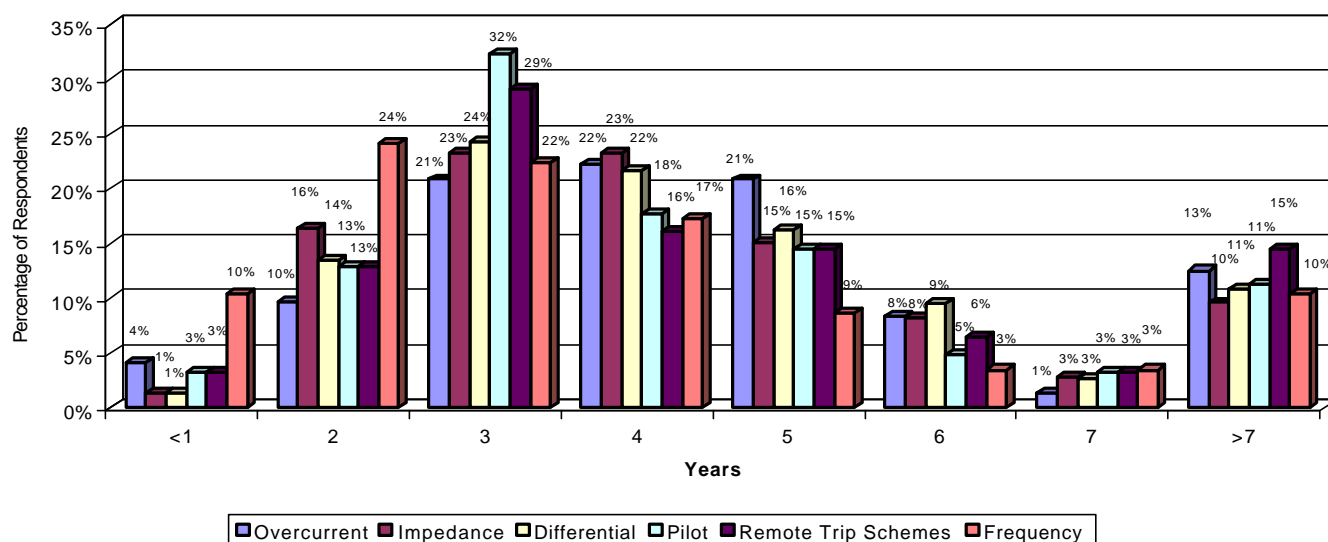


Figure 26: Time Intervals between Scheduled Relay Testing (years) - Electromechanical Relays on SUBTRANSMISSION Circuits

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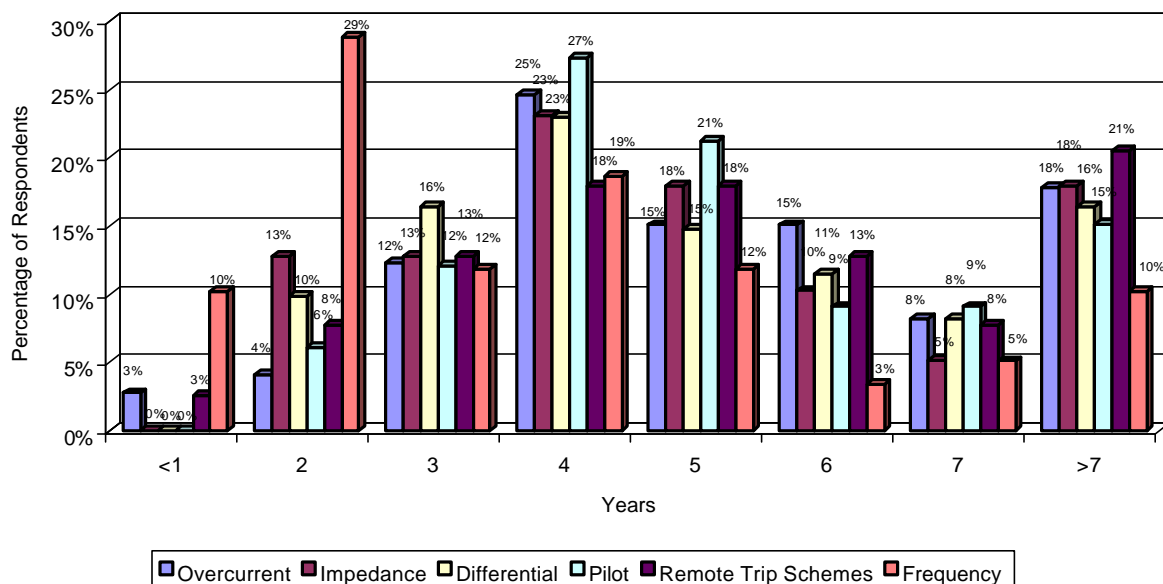


Figure 27: Time Intervals between Scheduled Relay Testing (years) - Electromechanical Relays on DISTRIBUTION Circuits

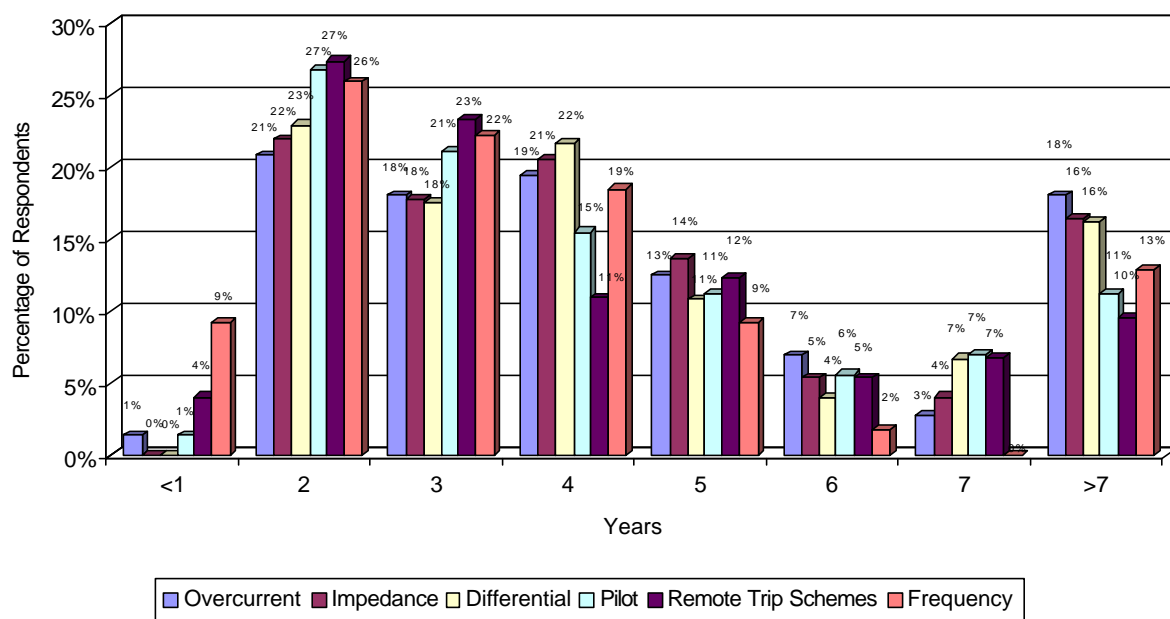


Figure 28: Time Intervals between Scheduled Relay Testing (years) - Non-Electromechanical Relays on TRANSMISSION Circuits

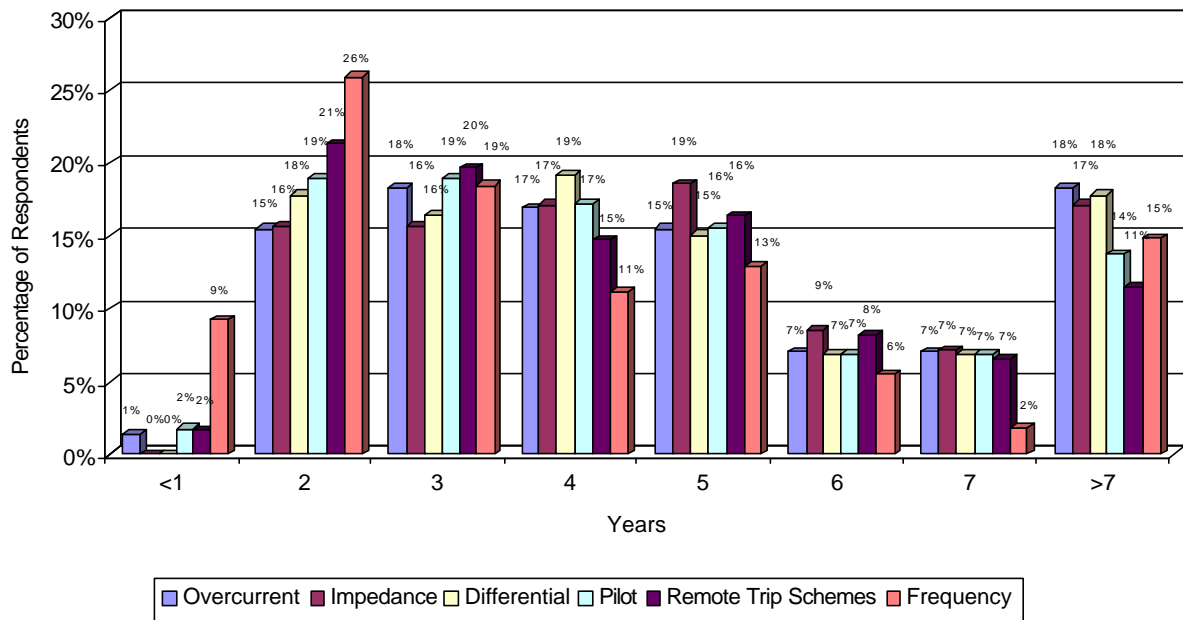


Figure 29: Time Intervals between Scheduled Relay Testing (years) - Non-Electromechanical Relays on SUBTRANSMISSION Circuits

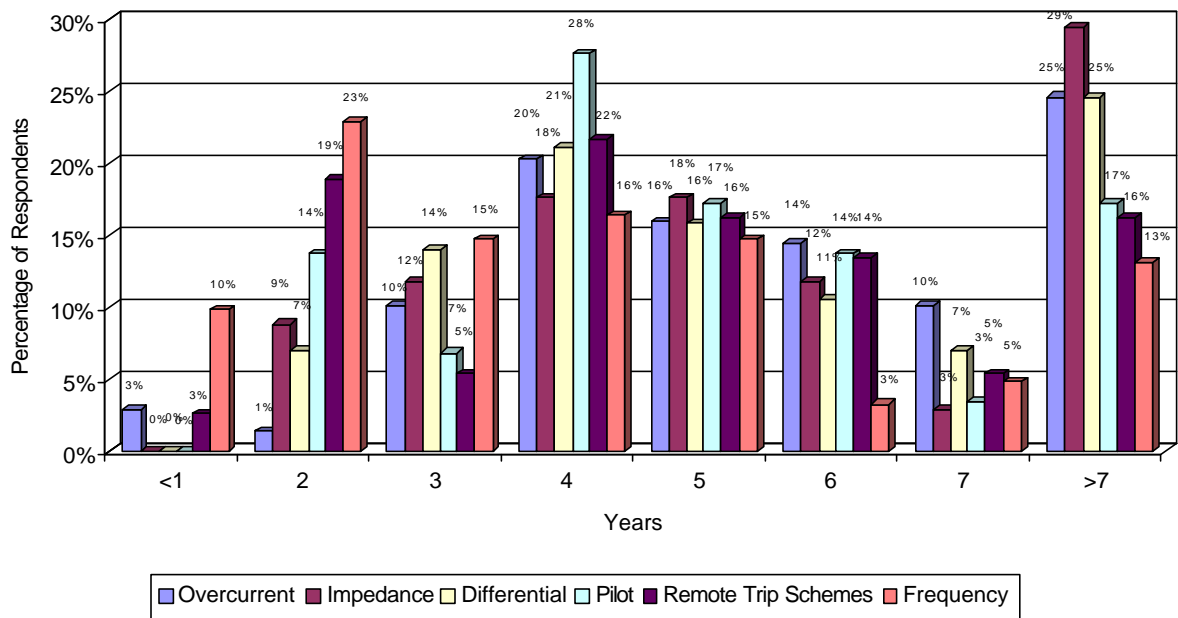


Figure 30: Time Intervals between Scheduled Relay Testing (years) - Non-Electromechanical Relays on DISTRIBUTION Circuits

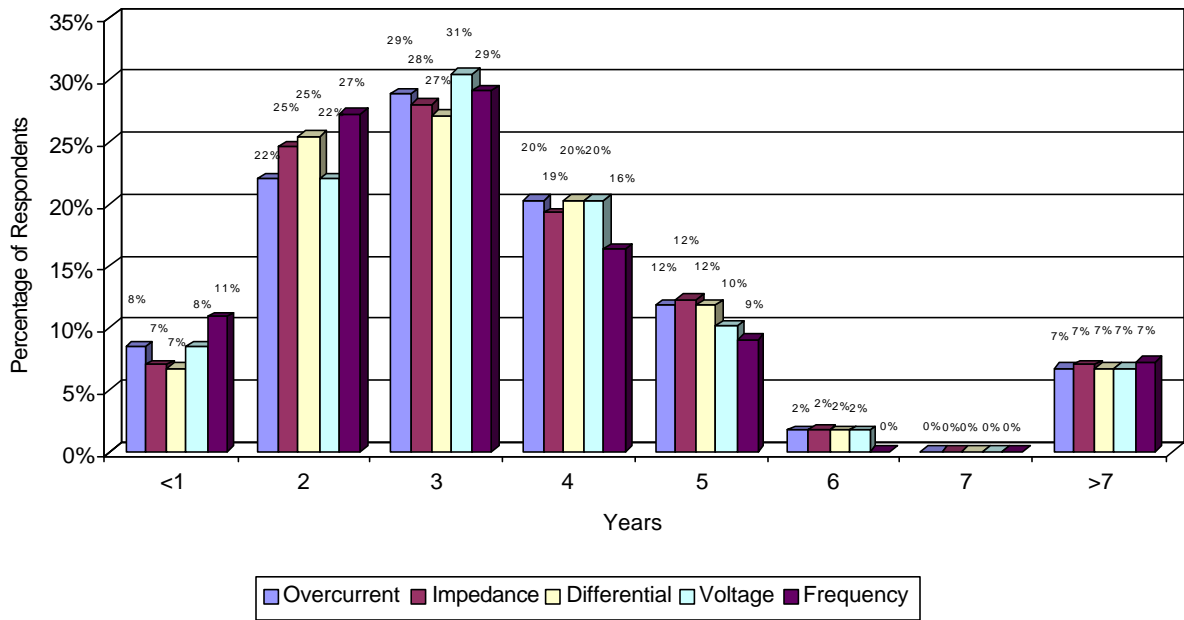


Figure 31: Time Intervals between Scheduled Relay Testing (years) - Electromechanical Relays for GENERATOR Applications at Non-Nuclear Power Stations

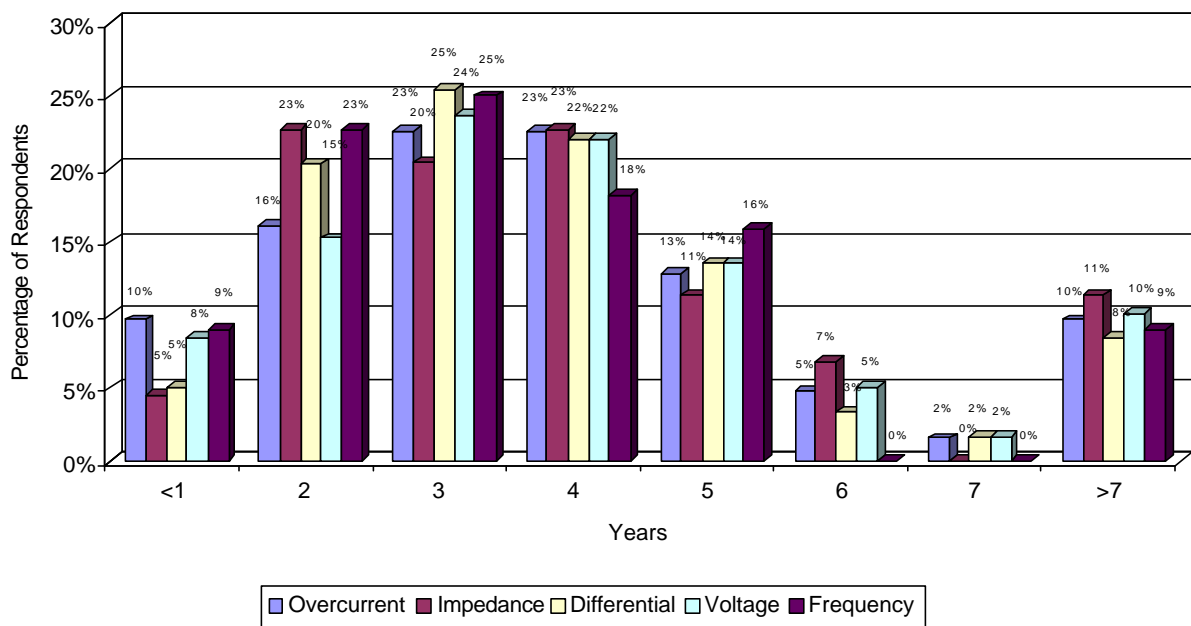


Figure 32: Time Intervals between Scheduled Relay Testing (years) - Electromechanical Relays for AUXILIARY BUS Applications at Non-Nuclear Power Stations

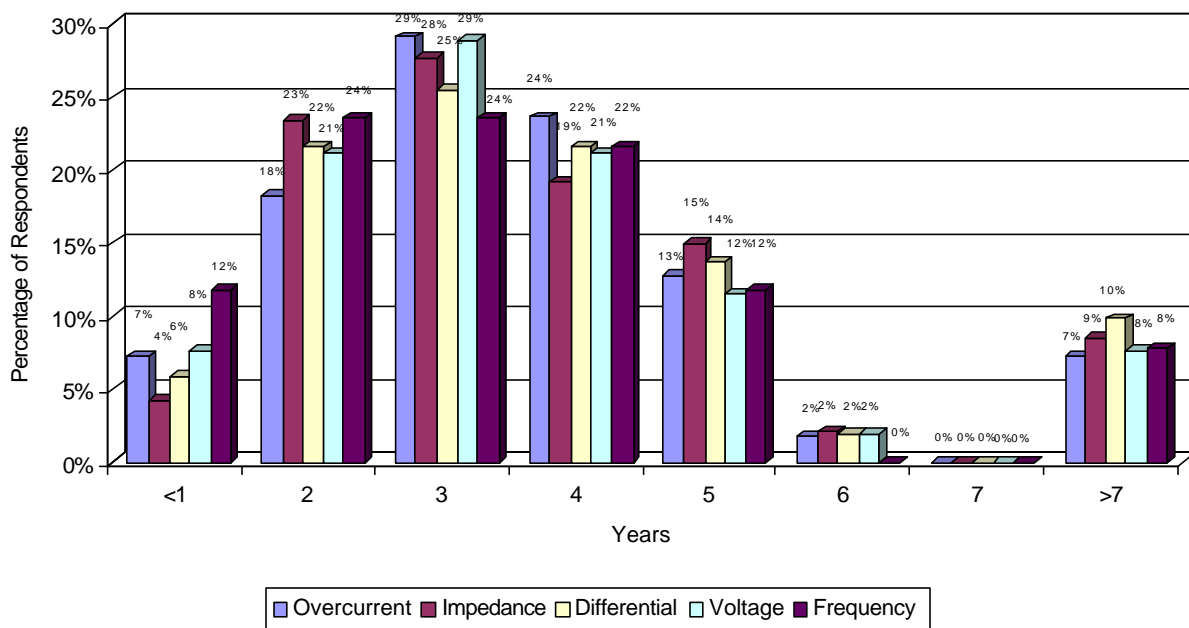


Figure 33: Time Intervals between Scheduled Relay Testing (years) - Non-Electromechanical Relays for GENERATOR Applications at Non-Nuclear Power Stations

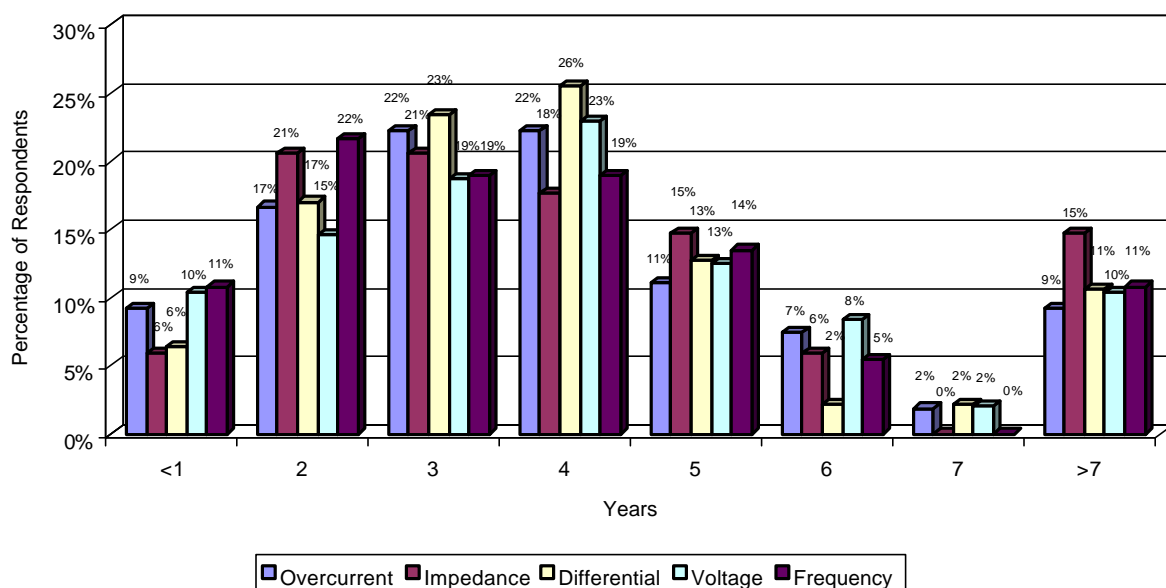


Figure 34: Time Intervals between Scheduled Relay Testing (years) - Non-Electromechanical Relays for AUXILIARY BUS Applications at Non-Nuclear Power Stations

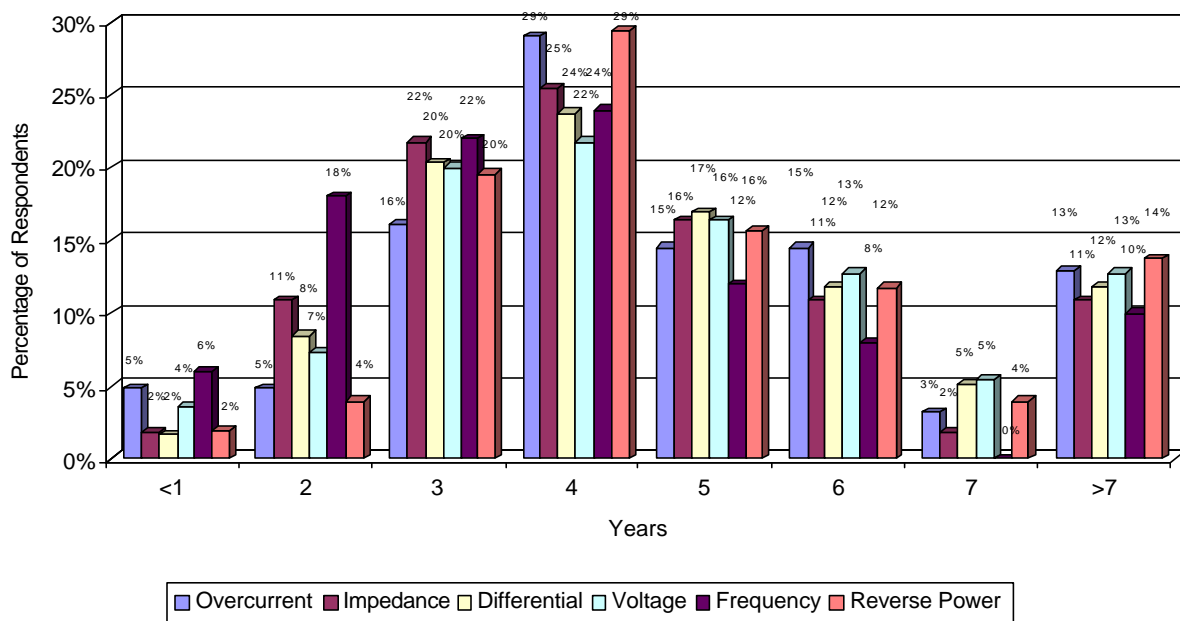


Figure 35: Time Intervals between Scheduled Relay Testing (years) - Electromechanical and Non-Electromechanical Relays for Substations Serving a LARGE INDUSTRIAL CUSTOMER

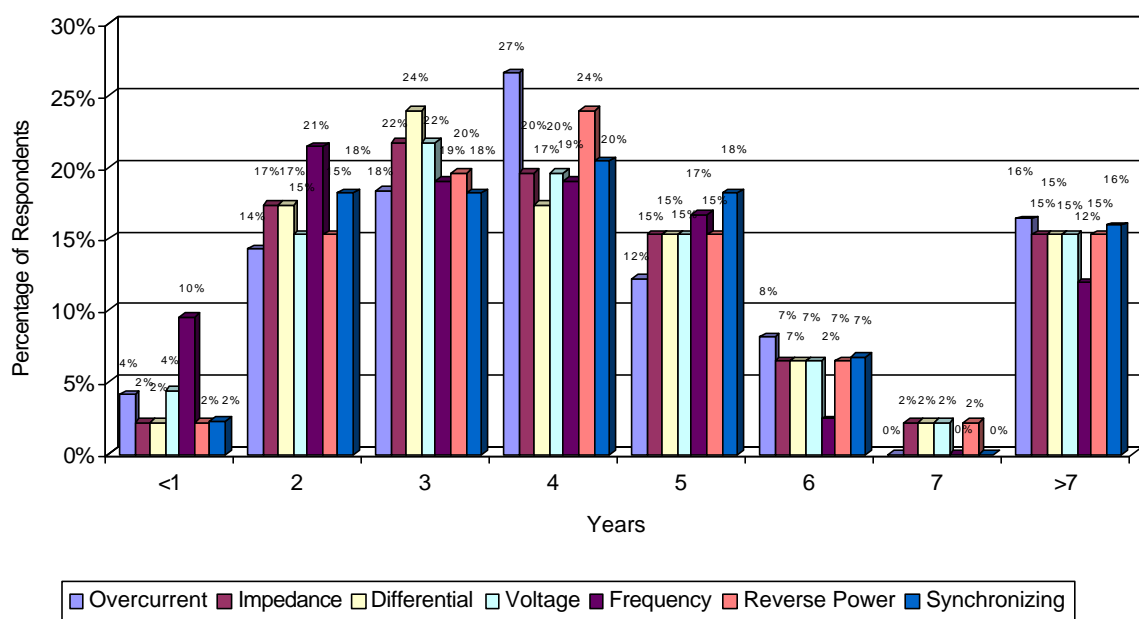


Figure 36: Time Intervals between Scheduled Relay Testing (years) - Electromechanical and Non-Electromechanical Relays for Substations Serving an INDEPENDENT POWER PRODUCER or Dispersed Source of Generation

## 6.2 Comparison of Relay Test Intervals with the 1991 Survey

Charts comparing maintenance and calibration intervals compiled during the 2001 survey as compared to the results of the 1991 survey is included in Figures 37 through 44.

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Over the ten-year interval, 1991 to 2001, one can see a shift in longer test intervals. For example, electromechanical impedance relays used for protection of transmission facilities were tested every five or more years by 28.9 % of the electric utilities responding in the 2001 survey, as compared to only 10.1 % in 1991. A similar shift in maintenance test intervals is found in comparisons of the data compiled in the two surveys for other relay types as well as indicated in Figures 37 through 44.

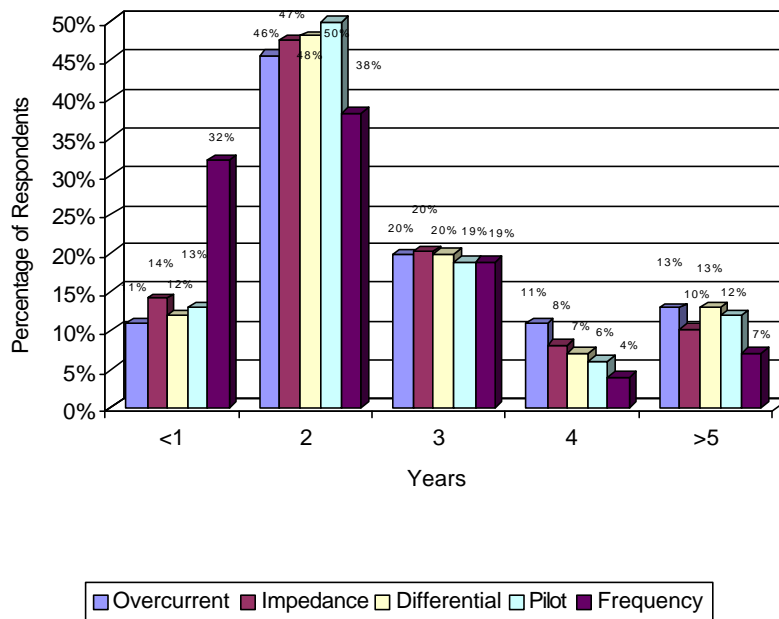


Figure 37: 1991 Survey – Electromechanical Relays - Transmission

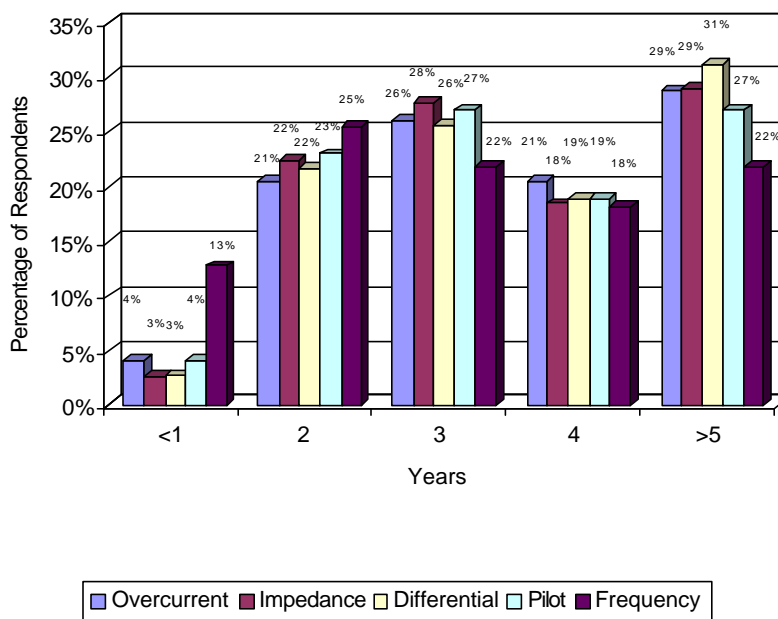


Figure 38: 2001 Survey – Electromechanical Relays - Transmission

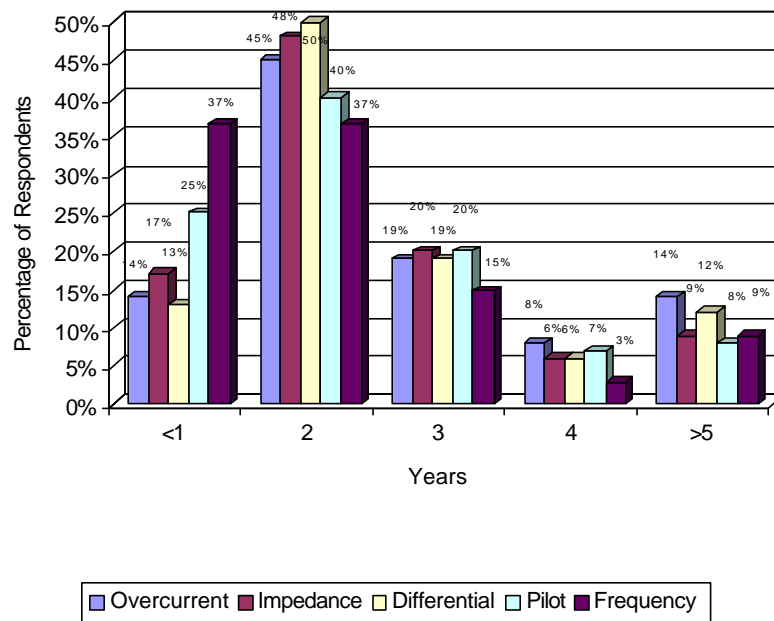


Figure 39: 1991 Survey – Non-Electromechanical Relays - Transmission

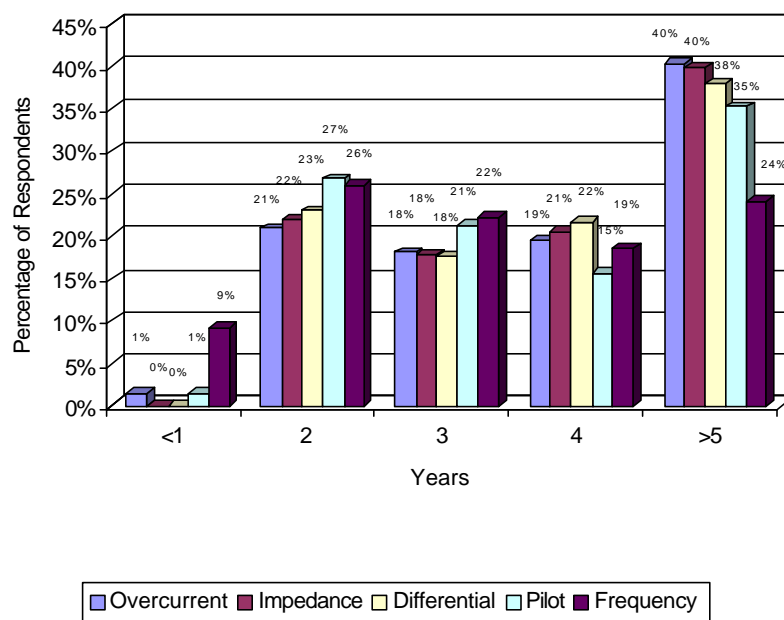


Figure 40: 2001 Survey – Non-Electromechanical Relays - Transmission



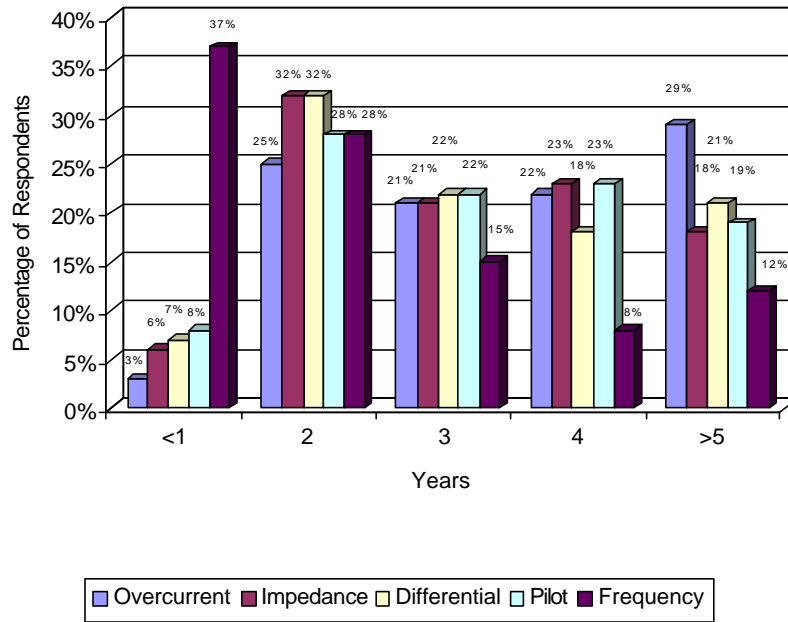


Figure 41: 1991 Survey – Electromechanical Relays - Distribution

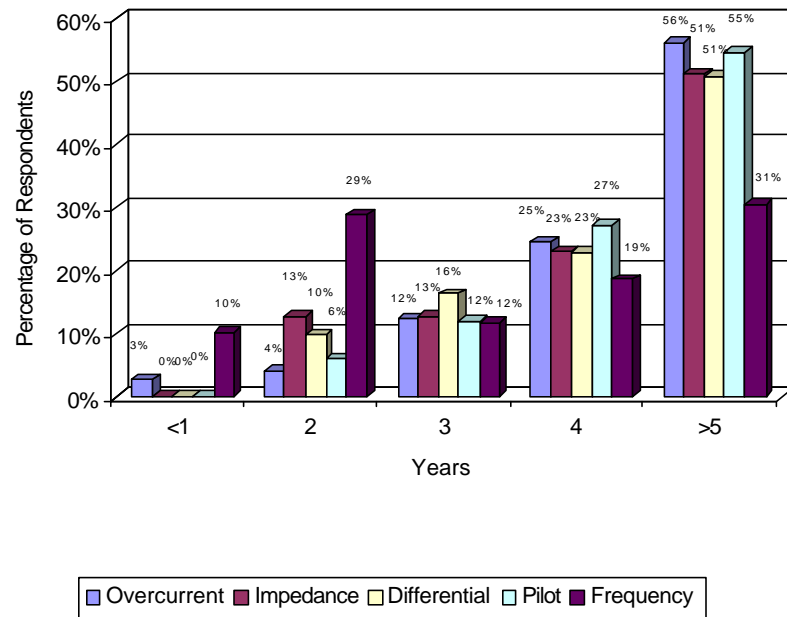


Figure 42: 2001 Survey – Electromechanical Relays - Distribution

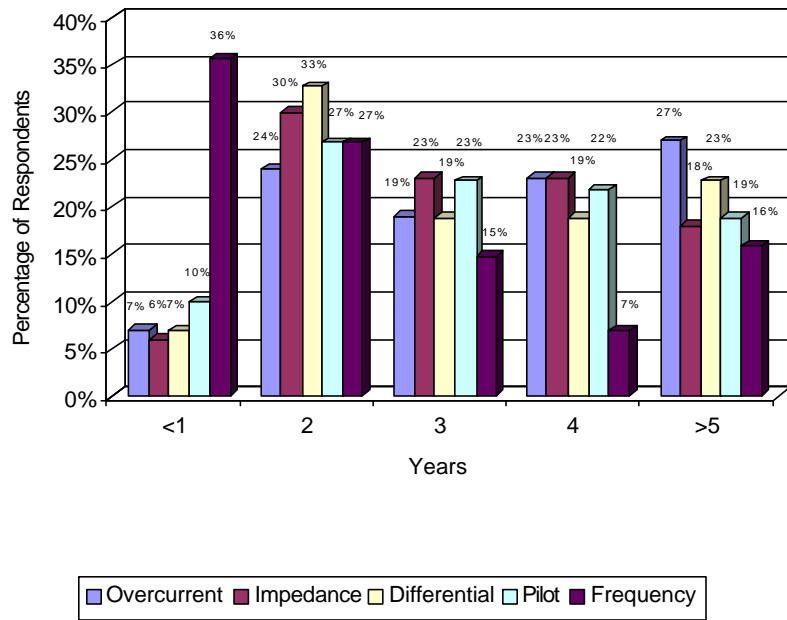


Figure 43: 1991 Survey – Non-Electromechanical Relays - Distribution

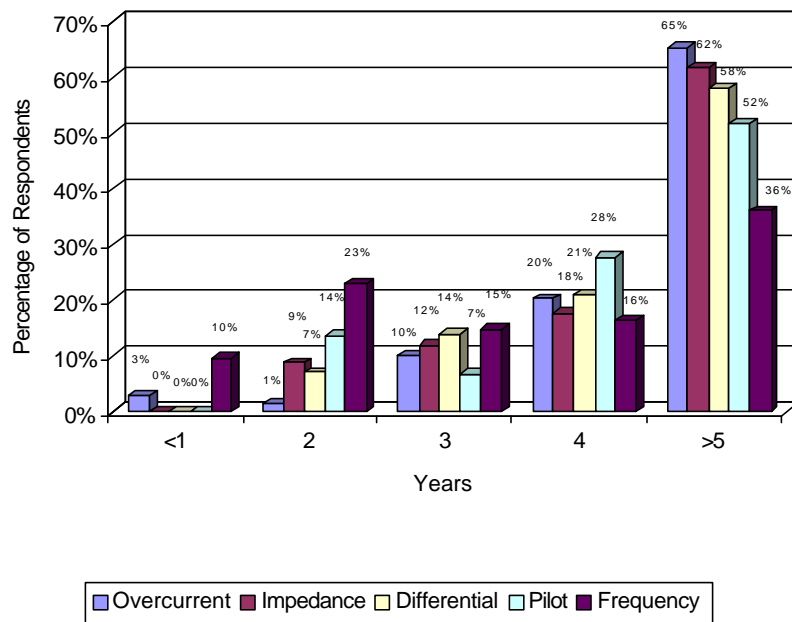


Figure 44: 2001 Survey – Non-Electromechanical Relays - Distribution

## 7. Relay Test Equipment

The purpose of this section is to compare what type of test equipment is being used, and for what type of applications. In addition, desired maximum weight is considered for transportability.

### 7.1 Acquisition of Test Equipment

According to the survey, fewer companies are building their own test sets. Over 97 % of those surveyed said that they procure commercially available relay test sets. Less than 3 % said that they build their own test sets.

### 7.2 Passive vs. Solid State Relay Test Sets

Passive relay test sets are defined as manually operated test sets comprised of resistive loads, mechanical phase shifters, variable autotransformers, or phantom loads. Solid state relay test sets include electronically regulated voltage and current sources. The survey showed that over 98 % of the respondents have two or more solid state relay test sets. As shown in Figure 45, almost half of the respondents, 49 %, use both passive and solid state relay test sets, while another 49 % use solid state test sets only. Less than 2 % use passive test sets only.

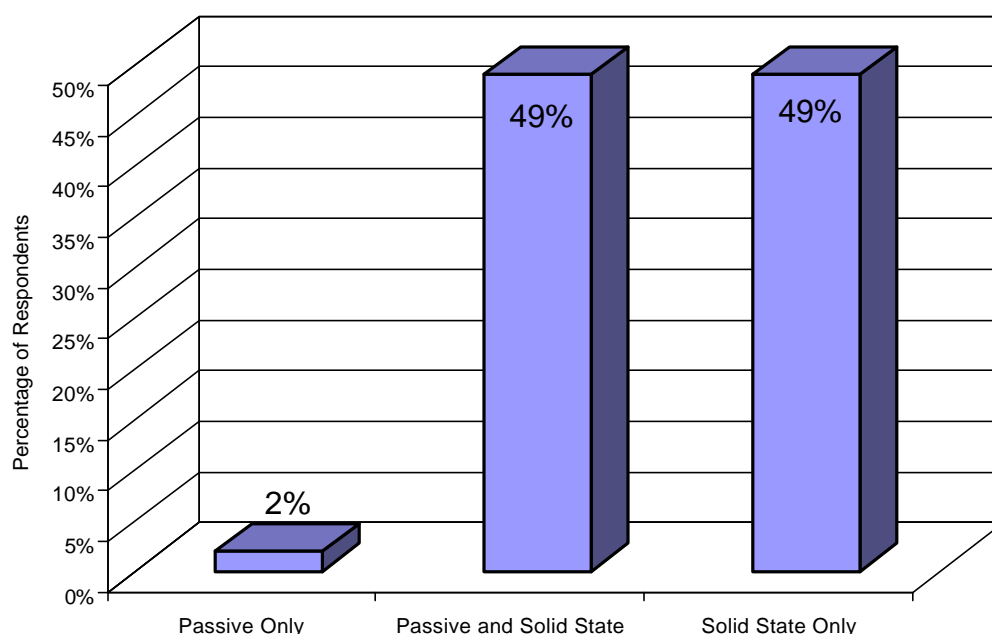


Figure 45: Percentage of Utilities that Use Passive and Solid State Test Sets

The ratio of passive vs. solid state test sets has dropped significantly since the 1991 survey. In 1991, 50 % of the test sets in use were passive loads. Today, of those surveyed, 29 % of the total number of units in use are passive loads (861 passive test sets out of a total of 2,965 units). Therefore, it is concluded that as the older passive units are retired they are being replaced with modern solid state relay test sets.

### 7.3 Dynamic Relay Test Equipment

Dynamic test equipment is defined as test sets capable of providing pre-fault, fault, and post-fault outputs, with dc and harmonic components. As shown in Figure 46, 80 % of the respondents have equipment with this type of capability. This is a significant increase from the 1991 survey, when only 50 % of respondents said that they had dynamic test equipment.

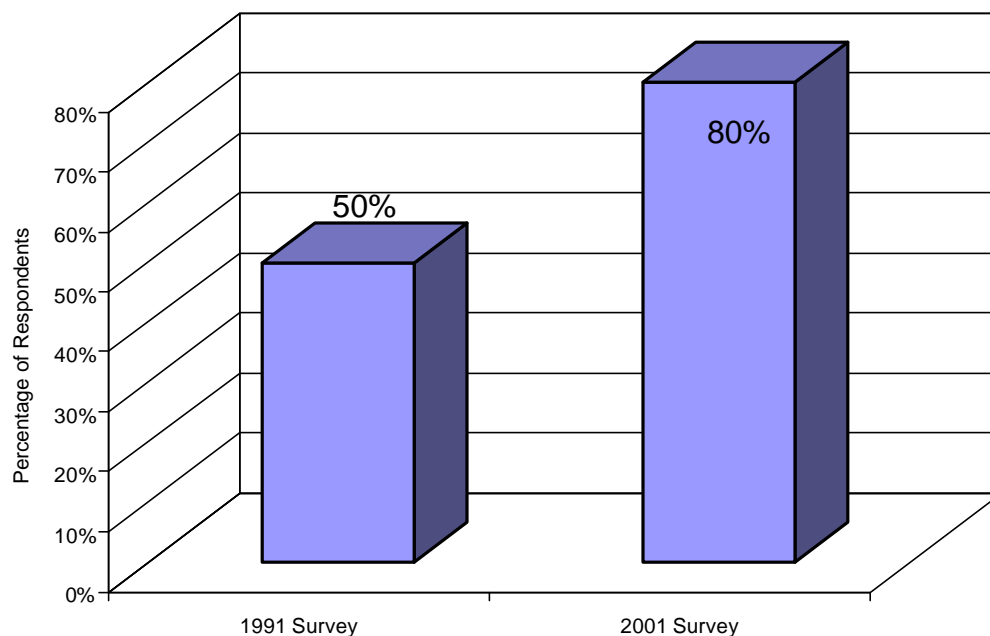


Figure 46: Percentage of Utilities that Use Dynamic Test Sets

#### 7.4 Power Swing Test Equipment

Utilities were asked if they have test sets capable of simulating power system disturbances such as power swings or frequency excursions. As shown in Figure 47, 79 % of the respondents have at least 1 test set capable of performing this type of test. This represents a 29 % increase from the 1991 survey.

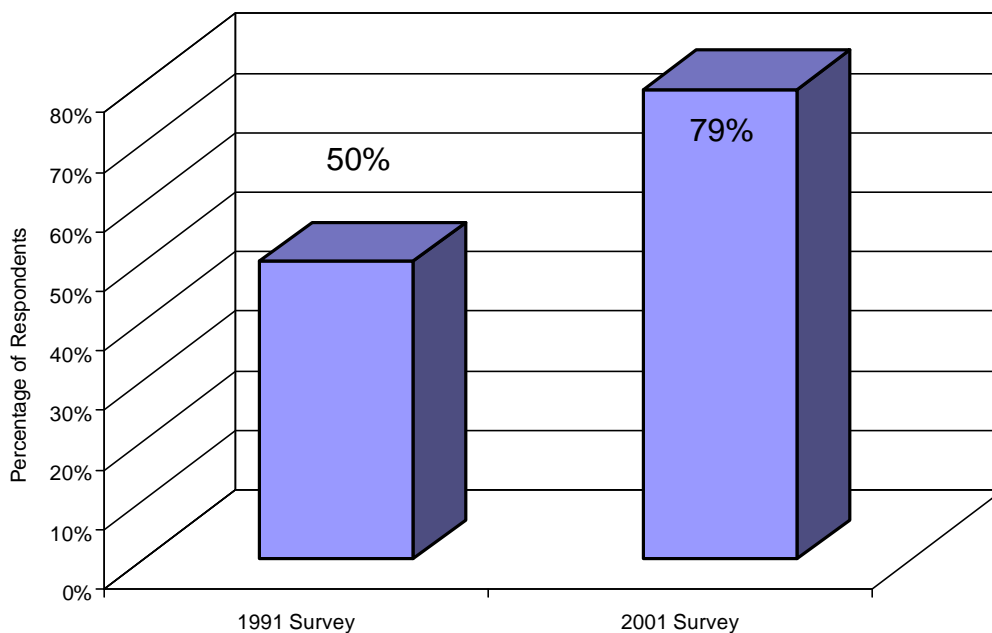


Figure 47: Percentage of Utilities that Use Power Swing Capable Test Sets

## 7.5 Computer Controlled Test Sets

This section of the survey focuses on the number of utilities who have purchased test sets with the capability of being controlled by a computer. As shown in Figure 48, 96 % of the respondents stated that they had test sets that could be controlled by a computer, an increase of 22 % from the 1991 survey. Only 73 % were actually using the computer to do automated testing, an increase of 21 % from the 1991 survey.

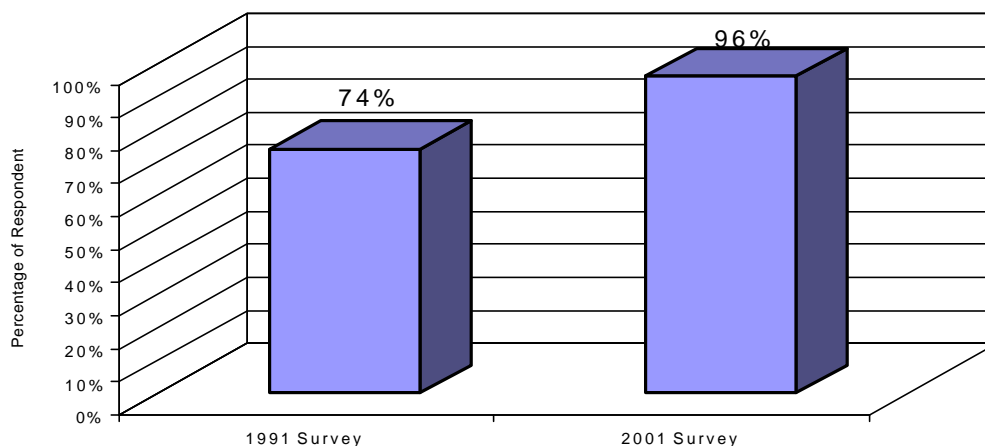


Figure 48: Percentage of Utilities that Use Computer Controlled Test Sets

## 7.6 COMTRADE Compatibility and Usage

IEEE Standard C37.111, also known as the COMTRADE Standard, specifies the machine readable file structure for transient recordings. Most modern commercially available relay test sets today have the capability to “playback” the recorded fault from digital fault recorders and other recording devices, including the relays themselves, which are in COMTRADE file format. As shown in Figure 49, 73 % of those surveyed said that they have test sets with this capability. However, of those who have the capability, 54 % are not using this feature. Of those who do use the feature, 7 % use it for routine testing, 41 % use it to analyze specific events (troubleshooting tool) and 13 % use it to evaluate new relays for purchasing. Some utilities commented that they have this capability, but have not had the opportunity to perform that type of testing. It is unknown what their intended use would be, but more than likely it would fall into one of the three listed above.

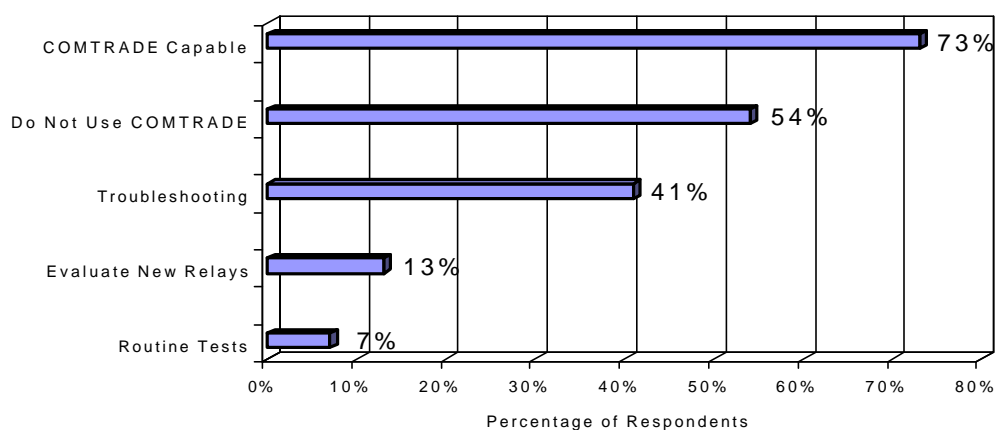


Figure 49: Percentage of Utilities that Use COMTRADE Capable Test Sets

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## 7.7 Portability of Test Equipment

Over 47 % of the respondents stated that they have relay test sets that require more than one person to carry. As shown in Figure 50, 50 % of the respondents said that the maximum weight should be 50 pounds or less. Another 47 % said that test sets that weighed from 50 to 80 pounds were acceptable, while 3 % said that test sets that weighed 80 pounds or more were acceptable.

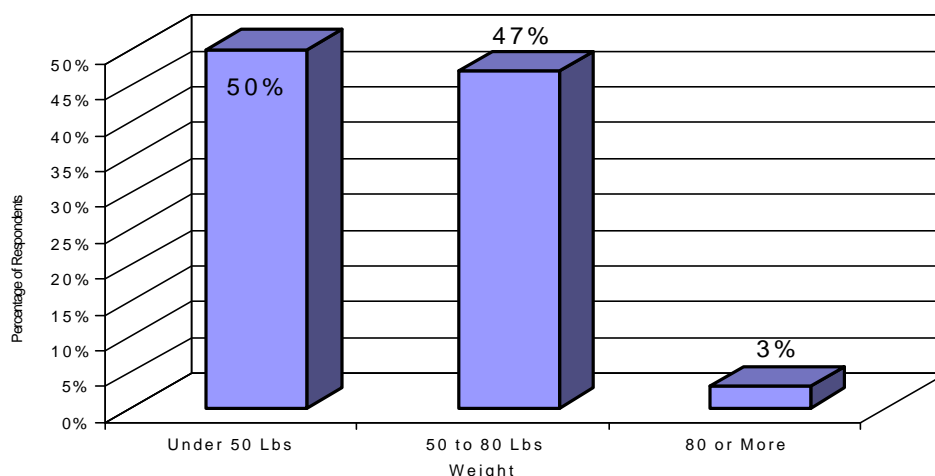


Figure 50: Desired Weights of Test Sets

## 8. Testing Protective Relays in a Particular Station

The purpose of this section is to determine how relay test crews are scheduled when relays are tested.

About 64 % of the respondents test all relays in a station with a single crew in one concentrated effort. Another 27 % of the respondents test relays at different times by different crews according to voltage, criticality and relay complexity. The remaining 9 % use other methods to schedule relay testing. Utilities who use a single crew in one effort increased about 11 % since the 1991 survey, while utilities that use different crews at different times decreased about 6 % since the 1991 survey. This implies that relay testing at utilities is moving towards “performing all relay testing in one effort”. Figure 51 shows these results.

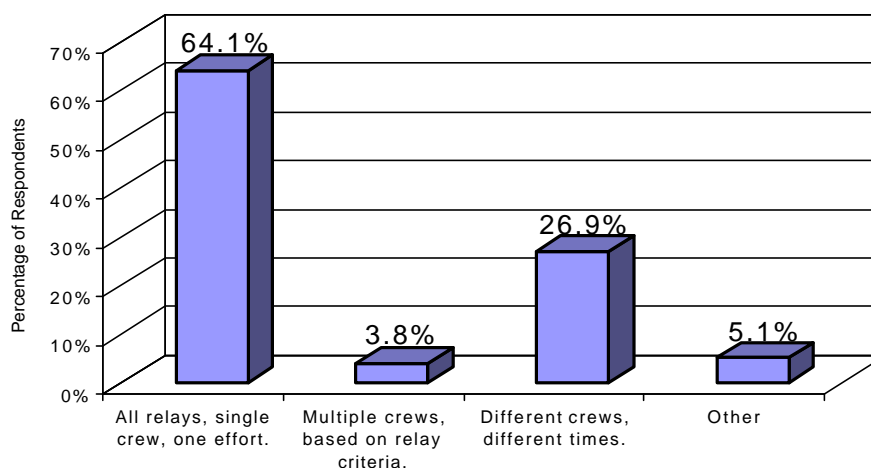


Figure 51: Utilities' Approach to Scheduling Relay Testing

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## 9. Protective Relaying Scheme Operational Test Conditions and Intervals

The purpose of this section of the survey is to determine the conditions for which protective relaying schemes are operationally tested and the intervals at which these tests are performed.

### 9.1 Operational Trip Testing

Most individuals responsible for power system protection consider operational trip testing necessary to verify that all relays, power circuit breakers, station batteries and other equipment are performing correctly. This section addresses when these operational checks are performed, how often are they performed and who performs the operational check.

Power circuit breakers are trip tested with their protective relays during various routine maintenance tasks and when a malfunction or misoperation is suspected. If a misoperation is suspected, a majority of respondents said they perform a trip check. For routine maintenance, operational trip checks of the power circuit breakers during both relay and breaker maintenance is a very common utility practice. The results are shown on Figure 52.

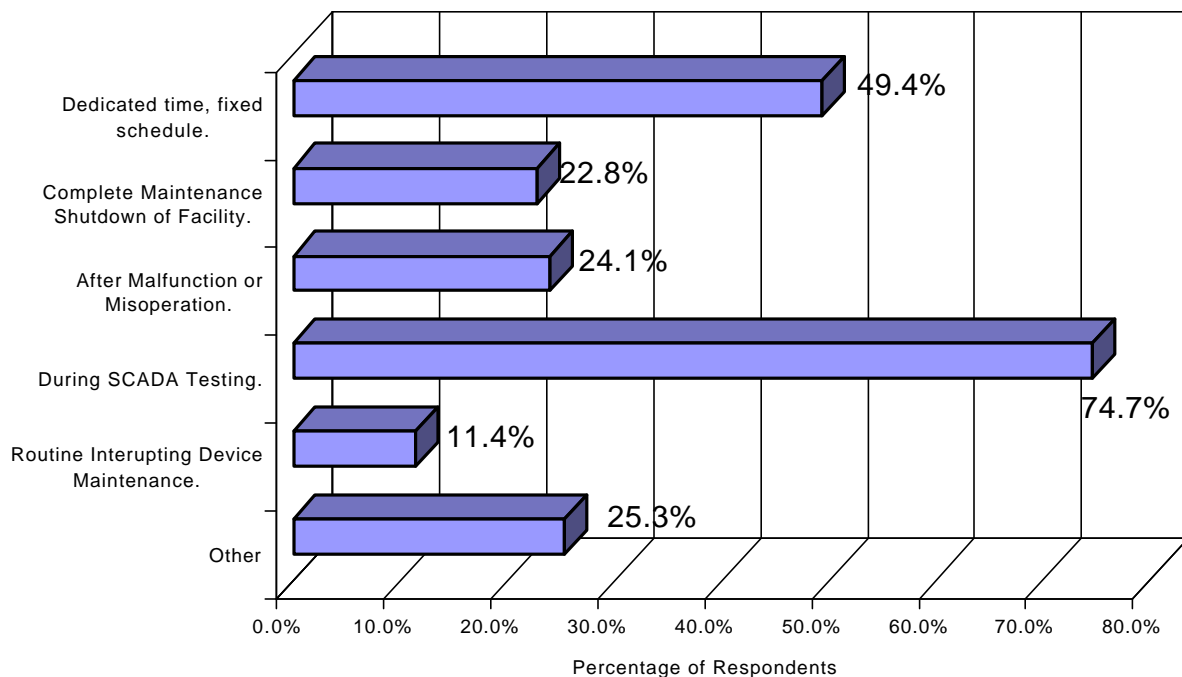


Figure 52: Other Testing Performed when Utilities Perform Operational Trip Testing

### 9.2 Operational Trip Test Intervals

The majority of relay schemes were operationally trip tested on a 1 to 3 year cycle. The results are shown on Figure 53.

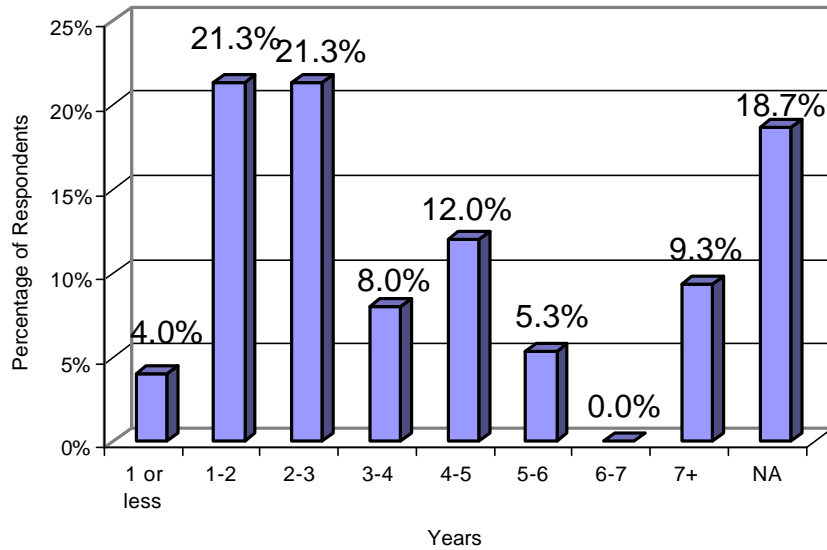


Figure 53: Operational Testing Intervals

### 9.3 Personnel Who Perform Operational Trip Tests

As can be seen from Figure 54, maintenance and service personnel along with protection technicians are most likely to be performing these trip tests.

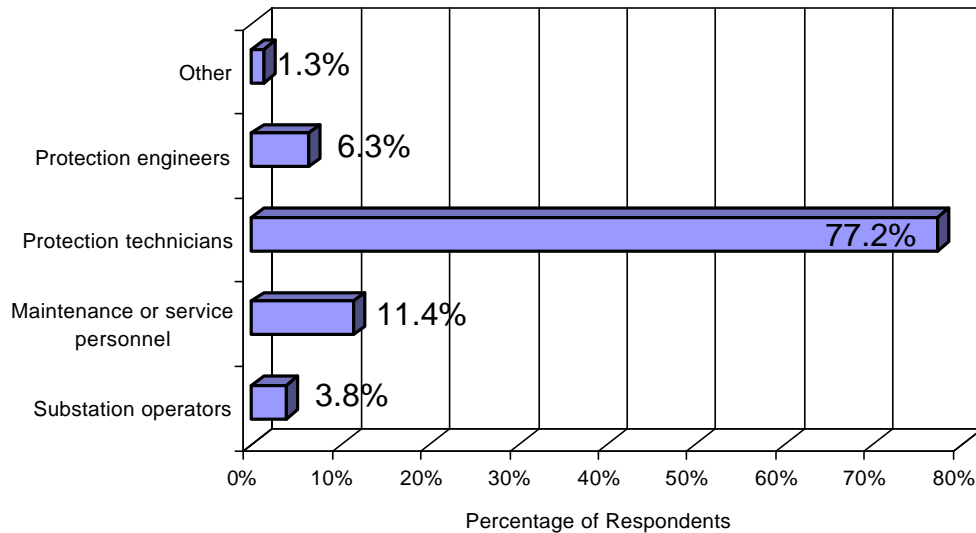


Figure 54: Type of Personnel Who Perform Trip Testing

## 10. Maintenance Program Effectiveness

The purpose of this section was to determine how utilities decrease relay failures through their maintenance programs.

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## 10.1 Criteria Used

As shown in Figure 55, “Reliability” was the chosen as the most common criteria used to measure maintenance program effectiveness, while the second most common selection was “Productivity and Performance”.

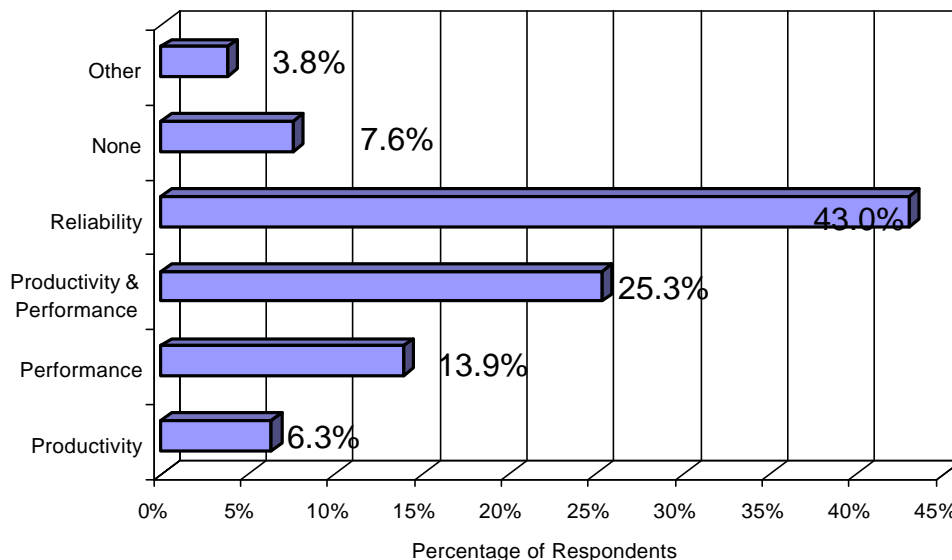


Figure 55: Basis for Measurement Criteria to Determine Effectiveness of Maintenance Programs

## 10.2 Correlation between Measurements and Failure Rates

As shown in Figure 56, 25.3 % of the respondents said that there is a relationship between their measurements and a reduction in failure rates. This is a 5.8 % increase from 1991 survey.

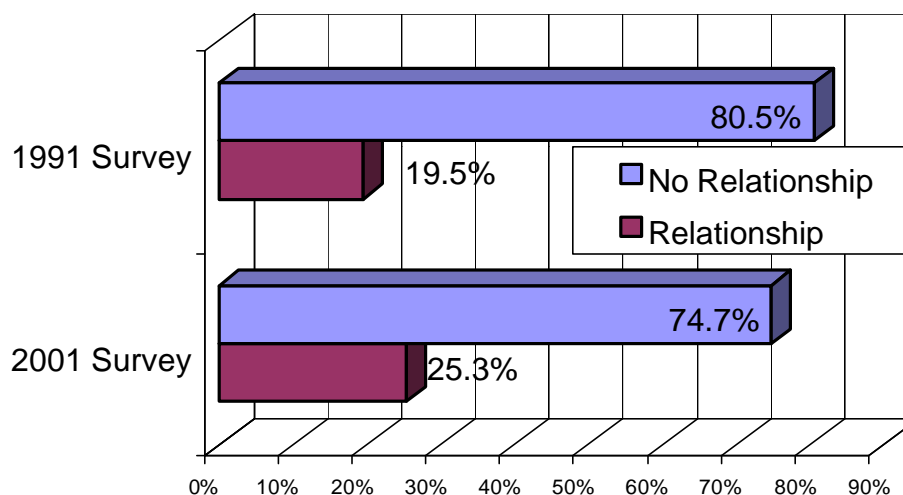


Figure 56: Percentage of Utilities Who Identify a Relationship Between Measurement and Failure Rate

### 10.3 Satisfaction of the Utilities' Maintenance Programs

In rating the effectiveness of their utility's maintenance program, 25.3 % of the respondents were very satisfied, 58.2 % were satisfied, 13.9 % were unsatisfied and 2.5 % were very unsatisfied. The satisfaction level seems to be slightly lower then in the 1991 survey. Figure 57 shows the survey results.

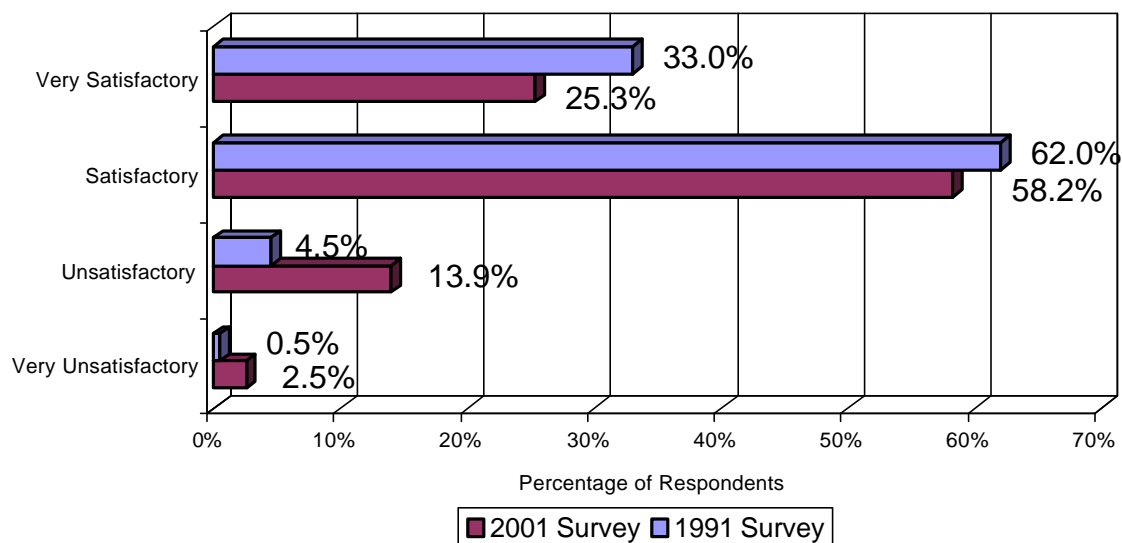


Figure 57: Utility Opinions on Effectiveness of Maintenance Programs in Reducing Relay Failures

## **11. Bibliography**

- [1] A Survey of Relay Test Practices, IEEE Power Systems Relaying Committee Report, IEEE Transactions Power Apparatus and Systems, Vol. 91, pp. 1191-1196, May/June 1972.
- [2] A Survey of Relay Test Practices, IEEE Power Systems Relaying Committee Report, IEEE Transactions Power Delivery, Vol. 9, No. 3, pp. 1339-1351, July 1994.

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