Annex K

Report of Circuit Breaker Reliability Survey of Industrial and Commercial Installations

By
A.T. Norris

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REPORT OF CIRCUIT BREAKER RELIABILITY SURVEY OF INDUSTRIAL AND COMMERCIAL INSTALLATIONS

Andrew Norris (coordinating Author)[1]

CIRCUIT BREAKER RELIABILITY WORKING GROUP
POWER SYSTEMS RELIABILITY SUBCOMMITTEE
POWER SYSTEMS ENGINEERING COMMITTEE
INDUSTRIAL & COMMERCIAL POWER SYSTEMS DEPARTMENT
IEEE INDUSTRY APPLICATIONS SOCIETY

ABSTRACT

The Reliability Subcommittee of the IEEE Industry Applications Society initiated a survey of the reliability of circuit breakers in industrial and commercial installations in keeping with its commitment to update information on previous surveys. The survey was restricted to circuit breakers that are less than fifteen (15) years old, and excluded molded case breakers, in order to provide information on units of interest and to obtain information on new circuit breaker technologies.

A more detailed explanation on reasons for this survey is included in the appendix.

INTRODUCTION

The results of the survey conducted in 1985 on the reliability of circuit breakers in industrial and commercial installations are summarized in the attached tables. The data obtained includes information on estimated numbers of operations per year for both fault and non-fault situations. Information has also been collected on low voltage circuit breakers comparing static and electro-mechanical integral trip devices.

Each table is discussed to highlight results of the survey. It is the intent of this working group to present the results as updated information on industrial applications and the drawing of definite conclusions is left to the reader.

The reasons for conducting the survey were written down at the beginning and are included in the appendix. Some of these objectives were not achieved due to the small number of participants in the survey. It was not possible to determine the effect of preventive maintenance on failure rate. Insufficient data were submitted on vacuum and single-pressure SF-6 circuit breakers.

[1] The Author is with the University of Missouri - Columbia, Missouri 65211

Members of the Circuit Breaker Reliability Working are Andrew T. Norris (Chairman), James W. Aquillino, William F. Braun, Jr., Charles R. Heising, Don O. Koval, Lou D. Monaghan, Pat O'Donnell, A.D. Patton, and Peter W. Dwyer.

SURVEY RESPONSE

The survey questionnaire, along with the Reasons For Conducting a New Survey on Circuit Breaker Reliability, is included in the appendix.

Due to the low number of responses, 13 plant locations, no attempt was made to separate failures by industry types. While the number of respondents was less than hoped for, the questionnaires were all fully completed for the requested data, with only one (1) "unknown" entry listed which was for a failure duration.

The following list provides a summary of the survey response

No. of Plants	13
No. of Circuit Breakers	2137
Sample Size (unit years)	4097.17
Total no. of Failures	59

The small sample size of the data received limited the results that are being published to four equipment/voltage categories. A special note is made in the tables where the number of failures in a specific category is considered an inadequate sample size. Less than 8 failures has been considered as an inadequate sample size.

OVERALL SUMMARY OF RELIABILITY DATA

Table 1 summarizes the overall results by voltage class. The low number of failures (4) in the 601 volt to 15,000 volt circuit breaker class makes this failure rate data of questionable validity.

This survey shows an increase in the failure rate per unit-year, in the 0-600 volt class, of nearly 3 times the value shown in the 1973 survey. There is, however, a large reduction in the average and maximum failure durations of 30% and 99.5% respectively.

LOCATION

Table 2 shows the effect of outdoor vs. indoor location on the failure rate of 0 - 600 volt circuit breakers. The failure rate was 1.54 times higher for outdoor circuit breakers.

INTEGRAL TRIP

Table 3 compares the integral trip unit type on the failure rate for 0-600 volt circuit breakers. The failure rate of static type integral trip units is 36% of the electromechanical units.

FAILURE MODE

Table 4 shows the failure modes for circuit breakers reported in the survey. It is noted that there were only two instances of units that "failed to open on command", and no occurrences of "closes without command". In the 0-600 volt class all circuit breakers reported had an integral trip device. The circuit breakers with a static integral trip device were split between "failed to close on command" (44%), and "opens without command" (56%). Circuit breakers with electro-mechanical type of integral trip device had a very large portion (93%) of the failures reported to be "failed to close on command".

FAILURE INITIATING CAUSE

Table 5 shows the primary failure initiating cause reported for both 34.5-138kV and 345kV circuit breaker groups as "mechanical breakdown" as 56% and 65% *respectively. The 0-600 volt circuit* breaker group shows "malfunction of protective relay or tripping device" to be the major category at (93%) for units with electro-mechanical integral tripping. The 0-600 volt units with static type integral tripping reported a roughly even split between "transient overvoltage" and "malfunction of protective relay or tripping device".

FAILURE CONTRIBUTING CAUSE

Table 6 shows that "dust, salt spray, or other contaminant exposure" is the primary reported listing (at 93%) for failure contributing cause for 0-600 volt circuit breakers with electro-mechanical type integral trip. The 0-600 volt circuit breakers with static integral trip had "lack of preventive maintenance" reported for 56% of failures, with the remaining 44% shown as "persistent overload". Entries for other voltage classes are in much lower percentages, except for the "other" category in the 34.5-138kV and 345kV groups.

SUSPECTED FAILURE RESPONSIBILITY

In table 7 the data shows most 0-600 volt breakers with electro-mechanical type of integral trip as having "inadequate physical protection" (93%) as the suspected failure responsibility. The 0-600 volt breakers with static type integral trip reports 56% under "improper operation", and 44% under "inadequate maintenance". The 34.5-138kV and 345kV voltage categories both show "defective component" as the main category.

FAILURE DISCOVERED DURING

Table 8 shows a very large percentage of failures in the 0-600 volt circuit breakers, a total of 98%, as being discovered "during normal operation". The 34.5-138kV class showed a significant percentage of failures (67%) as being discovered "during routing testing/maintenance", while the 345kV breakers were split between "during routing testing/maintenance" and "during normal operation" with 46% in each category.

FAILURES vs. MONTHS SINCE LAST MAINTENANCE

Table 9 shows that most failures occurred within 24 months of the last maintenance.

FAILURE REPAIR METHOD

Table 10 shows that a high percentage of circuit breakers in the 0-600 volt, 601-15,000 volt, and 34.5-138kV ratings were "repaired failed component in place or sent out for repair".

The 345kV group of circuit breakers shows the highest number (44%) as "replaced failed unit with spare". This large percentage is considered questionable since an inspection of the failed component entries showed in some cases that a failed component, such as an air compressor, was reported as "replaced failed unit with spare".

REPAIR URGENCY

It is of particular interest that, in Table 11, only 7% of the 59 failures reported for all voltage categories listed the repair urgency as requiring working on a round-the-clock bases. This *may be due, at least in part, to the fact* that two of the voltage classes (0-600 volt, and 601-15,000 volt) containing 45% of the total failures, and had maximum failure durations of 4 hours.

The 34.5-138kV and 345kV circuit breakers, with their longer failure durations, also show nearly all repair work as normal working hours.

POPULATION OF CIRCUIT BREAKERS vs. MAINTENANCE QUALITY AND NORMAL MAINTENANCE CYCLE

Table 12 shows the majority of respondents (53%) considered themselves as having a "fair" maintenance quality, while 39% considered their maintenance quality as "excellent". All of the respondents who listed their maintenance quality as excellent had a normal maintenance cycle of 0-24 months. The respondents with "fair" maintenance quality were split between categories with 37% (by unit-year) showing 0-24 month, 28% (by unit-year) showing more then 24 months and, interestingly enough, 35% with No preventive maintenance.

OVERALL CIRCUIT BREAKER
OPERATIONS PER YEAR DATA

The listing of "overall circuit breaker operations data" has been entered in three different tables.

Table 13a shows the data entered in a non-weighted format. The fault, and non-fault, operations per year are based on non-weighted numbers. The non-weighted values were obtained by counting each population data line entry as one unit (regardless of how many circuit breakers or unit-years were reported in that line). The average number of operations for each entry line were summed and the result divided by the number of line entries.

Table 13b shows the data weighted by the number of circuit breakers. The fault and non-fault operations per year are based on the actual number of circuit breakers reported, regardless of time in service. The average number of operations for each entry line was multiplied times the number of circuit breakers reported for that line. The resulting values were summed and the total was then divided by the number of circuit breakers reported in that voltage category.

Table 13c shows the data weighted by the number of unit-years. The fault and non-fault operations per year are based on the number of circuit breakers reported times their number of years in service (unit-years). The unit-years for each circuit breaker times the average operations per year was summed and the result divided by the total number of unit-years reported in that voltage category.

With the exception of the 0-600 volt category, the average number of operations per year remained reasonably consistent over the three tables.

Table 1 – OVERALL CIRCUIT BREAKER RELIABILITY DATA

	0-600 Volt * Air Magnetic	601-15,000 Volt *** Air Magnetic	34.5-138 kV Bulk Oil	345 kV Air Blast & SF-6 (2 presure)
Sample Size (number of units)	1695	315	64	51
Sample Size (unit-years)	2941.24	694.76	192.50	256.00
Total Fault Operations (for all unit-years)	225	343	103	434
Total Non-Fault Operations (for all unit-years)	24604	24914	4320	6200
Number of Failures	23	** 4	9	23
Failure Rate - Failures/Unit-Year	0.00782	** 0.00576	0.04675	0.08984
Failure Duration (Hours/Failure)		**		
Average	2.8	2.25	41.11	171.45
Minimum	0.5	1	1	1
Median	4	2	3	150
Maxumum	4	4	240	720

* Excludes Molded Case
** Small Sample Size - less than 8 failures (or data points)
*** Zero failures in 2.67 unit-years reported for Vacuum 601-15,000 volt (not included in this table)

NOTE: The "Total Fault Operations" and "Total Non-Fault Operations" were determined by taking the Unit-years (for each circuit breaker reported) times it's average number of operations (Fault or Non-Fault) per year, and adding the values for all circuit breakers in that catagory.

Table # 2 CIRCUIT BREAKERS, 0-600 VOLT*
OUTDOOR versus INDOOR LOCATION

	Outdoor	Indoor
Sample Size (unit-years)	873.57	2067.67
Number of Failures	9	14
Failure Rate - Failures/Unit-Year	0.0103	0.00677

* Excludes Molded Case

Table # 3 CIRCUIT BREAKERS, 0-600 VOLT*
EFFECT OF INTEGRAL TRIP TYPE

	Static	Electro-mechanical
Sample Size (unit-years)	1888.49	1052.75
Number of Failures	9	14
Failure Rate - Failures/Unit-Year	0.00477	0.0133

* Excludes Molded Case

TABLE # 4 - CIRCUIT BREAKERS
VOLTAGE VS. FAILURE MODE

	0-600 VOLT * Air Magnetic Static	0-600 VOLT * Air Magnetic Electro-mech	601-15KV Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
FAILED TO CLOSE ON COMMAND	4 44%	13 93%	-0-	3 33%	-0-
FAILED TO CLOSE AND LATCH	-0-	-0-	-0-	1 11%	-0-
FAILED TO OPEN ON COMMAND	-0-	-0-	2 50%	-0-	-0-
CLOSES WITHOUT COMMAND	-0-	-0-	-0-	-0-	-0-
OPENS WITHOUT COMMAND	5 56%	-0-	1 25%	-0-	7 30%
FAILED TO BREAK CURRENT WHEN OPENING	-0-	-0-	-0-	-0-	-0-
DAMAGED WHILE SUCCESSFULLY OPENING	-0-	-0-	1 25%	-0-	-0-
DAMAGED WHILE CLOSING	-0-	-0-	-0-	-0-	-0-
FAILED TO CARRY CURRENT	-0-	-0-	-0-	1 11%	-0-
FAULT TO GROUND, OR PHASE TO PHASE (NOT WHILE OPENING OR CLOSING)	-0-	-0-	-0-	-0-	-0-
FAULT ACROSS OPEN CONTACTS (NOT WHILE OPENING OR CLOSING)	-0-	-0-	-0-	-0-	-0-
LOSS OF VACUUM (FOR VACUUM BREAKERS)	-0-	-0-	-0-	-0-	-0-
OTHER FAILURE REQUIRING REMOVAL FROM SERVICE WITHIN 30 MINUTES	-0-	-0-	-0-	-0-	11 48%
OTHER FAILURE NOT REQUIRING REMOVAL FROM SERVICE	-0-	1 7%	-0-	3 33%	3 13%
UNKNOWN	-0-	-0-	-0-	1 11%	2 9%
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

TABLE # 5 - CIRCUIT BREAKERS
VOLTAGE VS. FAILURE INITIATING CAUSE

	0-600 VOLT * Air Magnetic Static	0-600 VOLT * Air Magnetic Electro-mech	601-15KV ** Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
TRANSIENT OVERVOLTAGE-SUCH AS LIGHTNING, SWITCHING SURGES, OR SYSTEM FAULTS	4 44%	-0-	1 25%	-0-	-0-
INSULATION BREAKDOWN	-0-	-0-	-0-	-0-	1 4%
MECHANICAL BURNOUT, FRICTION, OR SEIZING OF MOVING PARTS	-0-	-0-	-0-	-0-	1 4%
MECHANICAL BREAKDOWN - SUCH AS CRACKING, LOOSENING, ABRADING, OR DEFORMING OF STATIC OR STRUCTURAL PARTS	-0-	-0-	1 25%	5 56%	15 65%
PHYSICAL DAMAGE OR SHORTING FROM OUTSIDE SOURCE - SUCH AS VEHICULAR ACCIDENT	-0-	-0-	-0-	-0-	-0-
ELECTRICAL FAULT OR MALFUNCTION	-0-	-0-	1 25%	1 11%	3 13%
MALFUNCTION OF PROTECTIVE RELAY OR TRIPPING DEVICE	5 56%	13 93%	-0-	1 11%	-0-
OTHER AUXILIARY DEVICE MALFUNCTION	-0-	-0-	-0-	2 22%	-0-
LOW, OR NO, AUXILIARY VOLTAGE - FOR CIRCUITS SUCH AS AIR COMPRESSORS, AND SF-6 HEATERS	-0-	-0-	-0-	-0-	-0-
OTHER	-0-	1 7%	1 25%	-0-	3 13%
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

TABLE # 6 - CIRCUIT BREAKERS
VOLTAGE VS. FAILURE CONTRIBUTING CAUSE

	0-600 VOLT * Air Magnetic Static	0-600 VOLT * Air Magnetic Electro-mech	601-15KV ** Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
OVERLOAD - PERSISTENT	4 44%	-0-	1 25%	-0-	-0-
EXTREME HEAT	-0-	-0-	-0-	-0-	-0-
EXTREME COLD	-0-	-0-	-0-	-0-	3 13%
SEVERE WEATHER - SUCH AS WIND, RAIN, SNOW, OR SLEET	-0-	-0-	-0-	-0-	-0-
ABNORMAL MOISTURE	-0-	-0-	-0-	-0-	-0-
AGRESSIVE CHEMICALS	-0-	-0-	-0-	-0-	-0-
DUST, SALT SPRAY, OR OTHER CONTAMINANT EXPOSURE	-0-	13 93%	-0-	-0-	-0-
NORMAL DETERIORATION FROM AGE	-0-	-0-	-0-	2 22%	1 4%
LUBRICANT LOSS, OR DEFICIENCY	-0-	-0-	1 25%	1 11%	-0-
IMPROPER OPERATING OR TEST PROCEDURE	-0-	-0-	-0-	-0-	1 4%
TRIPPING SOURCE DEFICIENT	-0-	-0-	-0-	-0-	-0-
LACK OF PREVENTIVE MAINTENANCE	5 56%	-0-	1 25%	1 11%	-0-
OTHER	-0-	1 7%	1 25%	5 56%	18 78%
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

TABLE # 7 - CIRCUIT BREAKERS
VOLTAGE VS. SUSPECTED FAILURE RESPONSIBILITY

	0-600 VOLT * Air Magnetic Static	0-600 VOLT * Air Magnetic Electro-mech	601-15KV ** Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
DEFECTIVE COMPONENT	-0-	-0-	1 25%	4 44%	13 57%
IMPROPER HANDLING/SHIPPING	-0-	-0-	-0-	-0-	-0-
POOR INSTALLATION/TESTING	-0-	-0-	-0-	1 11%	1 4%
INADEQUATE MAINTENANCE	4 44%	-0-	-0-	1 11%	-0-
IMPROPER OPERATION	5 56%	-0-	1 25%	1 11%	-0-
IMPROPER APPLICATION	-0-	1 7%	-0-	-0-	-0-
INADEQUATE PHYSICAL PROTECTION	-0-	13 93%	-0-	-0-	-0-
OUTSIDE AGENCY (SUCH AS VEHICULAR ACCIDENT)	-0-	-0-	-0-	-0-	-0-
OTHER	-0-	-0-	2 50%	2 22%	4 17%
UNKNOWN	-0-	-0-	-0-	-0-	5 22%
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

TABLE # 8 - CIRCUIT BREAKERS
VOLTAGE VS. "FAILURE DISCOVERED DURING"

	0-600 VOLT * Air Magnetic Static	Electro-mech	601-15KV ** Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
DURING ROUTINE TESTING/MAINTENANCE	-0-	1 7%	1 25%	6 67%	11 48%
DURING NORMAL OPERATION	9 100%	13 93%	3 75%	3 33%	11 48%
OTHER	-0-	-0-	-0-	-0-	1 4%
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

** Small Sample Size - less than 8 failures (or data points)

TABLE # 9 - CIRCUIT BREAKERS
FAILURES VS. MONTHS SINCE LAST MAINTENANCE

***	0-600 VOLT * Air Magnetic Static	Electro-mech	601-15KV ** Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
0 - 24 MONTHS	-0-	14 100%	2 50%	8 89%	17 74%
OVER 24 MONTHS	9 100%	-0-	2 50%	-0-	6 26%
NO PREVENTIVE MAINTENANCE	-0-	-0-	-0-	1 11%	-0-
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

** Small Sample Size - less than 8 failures (or data points)

*** The survey requested data for 0-12 month and 12-24 month periods. Due to the uncertainty about which of these two periods should be used for entries of 12 months since maintenance, they were combined into a single entry of 0-24 months.

TABLE # 10 - CIRCUIT BREAKERS
VOLTAGE VS. FAILURE REPAIR METHOD

	0-600 VOLT * Air Magnetic Static	0-600 VOLT * Air Magnetic Electro-mech	601-15KV ** Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
REPAIRED FAILED COMPONENT IN PLACE OR SENT OUT FOR REPAIR	8 89%	13 93%	3 75%	7 78%	7 30%
REPLACED FAILED UNIT WITH SPARE	1 11%	1 7%	1 25%	2 22%	*** 10 43%
OTHER	-0-	-0-	-0-	-0-	6 26%
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

** Small Sample Size - less than 8 failures (or data points)

*** In some cases a failed component, not the complete breaker, was replaced with a spare.

TABLE # 11 - CIRCUIT BREAKERS
VOLTAGE VS. FAILURE REPAIR URGENCY

	0-600 VOLT * Air Magnetic Static	0-600 VOLT * Air Magnetic Electro-mech	601-15KV ** Air Magnetic	34.5KV-138KV Bulk Oil	345KV Air Blast & SF-6 (2 presure)
WORKING ROUND-THE-CLOCK	2 22%		1 25%	1 11%	-0-
NORMAL WORKING HOURS	7 78%	14 100%	3 75%	8 89%	23 100%
LOW PROIRITY	-0-	-0-	-0-	-0-	-0-
TOTAL FAILURES	9 100%	14 100%	4 100%	9 100%	23 100%

* Excludes Molded Case

** Small Sample Size - less than 8 failures (or data points)

TABLE # 12 - CIRCUIT BREAKERS
POPULATION OF CIRCUIT BREAKERS VERSUS
MAINTENANCE QUALITY & NORMAL MAINTENANCE CYCLE

MAINTENAN QUALITY	MAINTENANCE, NORMAL CYCLE * 0 - 24 MONTHS	MORE THEN 24 MONTHS	NO PREVENTIV MAINTENAN	TOTAL	
	POPULATION: UNIT-YEARS				
EXCELLENT	1198.25	383	-0-	1581.25	39%
FAIR	797.99	606.59	749.34	2153.92	53%
POOR	-0-	-0-	-0-	-0-	0%
NONE	-0-	-0-	362	362	9%

* The survey requested data for 0-12 month and 12-24 month periods. Due to the uncertainty about which of these two periods should be used for entries of 12 months since maintenance, they were combined into a single entry of 0-24 months.

Table 13a - OVERALL CIRCUIT BREAKER OPERATIONS DATA (Non-weighted)

	0-600 Volt * Air Magnetic	601-15,000 Volt Air Magnetic	34.5-138 kV Bulk Oil	345 kV Air Blast & SF-6 (2 presure)
Fault Operations/Year				
Average	0.175	0.3481	0.6945	1.1325
Minimum	0	0	0.05	0.2
Median	0.05	0.0769	0.75	2
Maxumum	1	1	2	2
Non-Fault Operations/Year				
Average	19.2834	47.5357	24.125	30
Minimum	0	0.5	3	10
Median	1.667	5	15	30
Maxumum	100	400	100	50

* Excludes Molded Case

To get the non-weighted values for Average Fault (and Non-Fault) Operations per year, each line entry was counted as one unit (reguardless of how many circuit breakers were reported in that line). The average number of operations for each entry line were summed and the result divided by the number of line entries. Twenty (20) line entries would be counted as 20 units, even though each line might represent 5 circuit breakers.

Table 13b - OVERALL CIRCUIT BREAKER OPERATIONS DATA (weighted by number of breakers)

	0-600 Volt * Air Magnetic	601-15,000 Volt Air Magnetic	34.5-138 kV Bulk Oil	345 kV Air Blast & SF-6 (2 presure)
Fault Operations/Year				
Average	0.0174	0.5898	0.4877	1.2341
Minimum	0	0	0.05	0.2
Median	0	1	0.75	2
Maxumum	1	1	2	2
Non-Fault Operations/Year				
Average	5.0932	27.1841	20.0156	35.098
Minimum	0	0.5	3	10
Median	5	25	20	30
Maxumum	100	400	100	50

* Excludes Molded Case

To get the weighted values (weighted by number of circuit breakers) for Average Fault, and Non-Fault operations, the number of operations for each entry line is multiplied by the number of circuit breakers reported in that line. The product (number of circuit breakers times average operations) from each line was summed and the result divided by the total number of circuit breakers reported in that catagory.

Table 13c - OVERALL CIRCUIT BREAKER OPERATIONS DATA (weighted by number of unit-years)

	0-600 Volt * Air Magnetic	601-15,000 Volt Air Magnetic	34.5-138 kV Bulk Oil	345 kV Air Blast & SF-6 (2 presure)
Fault Operations/Year				
Average	0.0787	0.4936	0.5375	1.6948
Minimum	0	0	0.05	0.2
Median	0.02	0.5	0.5	2
Maxumum	1	1	2	2
Non-Fault Operations/Year				
Average	8.3652	35.86	22.439	32.0313
Minimum	0	0.5	3	10
Median	1.6667	5	20	30
Maxumum	100	400	100	50

* Excludes Molded Case

To get the weighted values (weighted by number of unit-years) for Average Fault, and Non-Fault operations, the number of operations for each survey line entry is multiplied by the number of unit-years (circuit breakers reported in that line times the number years in service). The product (number of unit-years times average operations) from each line was summed and the result divided by the total number of unit-years reported in that catagory.

APPENDIX

REASONS FOR CONDUCTING A NEW SURVEY ON CIRCUIT BREAKER RELIABILITY

by Circuit breaker Reliability
Working Group
C. R. Heising, Coordinating Author
A. T. Norris, Chairman
J. W. Aquilino L. G. Monaghan
R. N. Bell P. O'Donnell
W. F. Braun A. D. Patton

The main purpose of this reliability survey is to identify failure data and the effect of pertinent factors on important classes and types of circuit breakers, thus providing the designer and planner the valuable basic information needed to install a reliable and economic industrial or commercial power system.

Previous IEEE-IAS circuit breaker reliability surveys of industrial & commercial installations were published in 1962 and in 1973/74. The latter has been included in IEEE Standard No. 493-1980 - "Recommended Practice for the Design of Reliable Industrial & Commercial Power Systems." Pertinent information from the new survey will be included in future revisions of IEEE Standard No. 493.

Some of the important objectives in this new survey are: 1. Obtain failure mode data, 2. Obtain estimates of the number of operating cycles per year, 3. Obtain data on static trip devices for low voltage circuit breakers, 4. Obtain information on the effect of preventive maintenance on failure rate, 5. Obtain better information on suspected failure responsibility, failure initiating cause, and failure contributing cause, and 6. Obtain pertinent information on new circuit breaker technologies.

33% or more of the failures reported in the 1973/74 survey did not contain information on suspected failure responsibility, failure initiating cause, and failure contributing cause. It is hoped that this can be improved upon in the new survey. This is considered important information when trying to improve the reliability of circuit breakers used on industrial & commercial power systems. In the 1973/74 survey 23% of the failures were blamed on the manufacturer and 23% were blamed on inadequate maintenance and 36% were unknown. These were the three largest causes of failures. Inadequate maintenance is an area that an industrial or commercial user can do something about; and any pertinent information on this subject will be requested.

The 1973/74 survey did not collect information on the estimated number of operating cycles per year. This is important information when trying to estimate the probability of a circuit breaker successfully operating when commanded to do so. This information will permit a reliability assessment versus duty application.

The 1973/74 survey did not collect low voltage circuit breaker data on whether of not a static trip device was used. This information is of interest to designers of power systems where there is much concern about failure rate of solid state versus electromechanical trip devices.

Approximately 30% of the circuit breakers in the 1973/74 survey were over ten years old. Circuit breakers more than 15 years old may not be typical of what is being used in the design of new power systems.

Various classes and types of circuit breakers in the 1973/74 survey had significantly different distributions of the various failure modes. Updated information on this subject is of interest to designers of power systems.

Reliability information on medium and high voltage circuit breakers using the newer technologies is of interest to designers of power systems. This includes vacuum and SF6-puffer circuit breakers.

Switchgear bus is not included in this survey. A separate survey was published on this subject in 1979. Protective relays, fuses, and switches are not included in this survey. A survey in 1978 on these equipment categories asked for information that many industrial and commercial users did not have readily available; and the survey was unsuccessful. A limited amount of information is contained in the 1973/74 survey on disconnect switches, relays, and fuses.

CIRCUIT BREAKERS

COMPANY NAME AND PLANT: ____________________

INDUSTRY TYPE: ____________________

PERIOD REPORTED - FROM: MONTH __________ YEAR __________

TO: MONTH __________ YEAR __________

LOCATION: ____________________

<u>TOTAL POPULATION</u>

A	B	C	D	E	F	G	H	I	J	K	L	M
IDENTIFICATION NUMBER	CIRCUIT BREAKER TYPE (Insert Code)	NUMBER OF BREAKERS	USED PRIMARILY AS MOTOR STARTER (1-YES, N-NO)	LINE-TO-LINE VOLTAGE (kV)	LOCATION (I-INDOOR, O-OUTDOOR)	INTEGRAL TRIP DEVICE* (1-YES, N-NO)	INTEGRAL TRIP IS (S-STATIC, EM-ELECTRO MECH)	EST. AVERAGE # OF NON-FAULT OPERATIONS/YEAR/BREAKER**	EST. AVERAGE # OF FAULT OPERATIONS/YEAR/BREAKER**	MAINTENANCE CYCLE (Insert Code)	MAINTENANCE QUALITY (Insert Code)	BRIEF DESCRIPTION OF MAINTENANCE

* IF TRIP INITIATION UNIT IS AN INTEGRAL PART OF THE BREAKER, INCLUDE ANY FAILURE OF THE TRIP UNIT AS A BREAKER FAILURE.

** CONSIDER EACH OPEN/CLOSE CYCLE AS ONE (1) OPERATION. INCLUDE OPERATIONS DURING MAINTENANCE.

CIRCUIT BREAKER

COMPANY NAME AND PLANT: ____________________

<u>FAILED UNIT DATA</u> - Fill in One Line for Each Failure

A	B	C	D	E	F	G	H	I	J	K
IDENTIFICATION NUMBER (FROM TOTAL POPULATION)	FAILURE DISCOVERED (INSERT CODE)	FAILURE INITIATING CAUSE (INSERT CODE)	FAILURE CONTRIBUTING CAUSE (INSERT CODE)	SUSPECTED FAILURE RESPONSIBILITY (INSERT CODE)	FAILURE MODE (INSERT CODE)	MONTHS SINCE LAST MAINTENANCE	REPAIR URGENCY (INSERT CODE)	FAILURE DURATION-HOURS	REPAIR OR REPLACE (INSERT CODE)	FAILED COMPONENT

CIRCUIT BREAKER RELIABILITY SURVEY
SURVEY CODE

Total Population Form

Circuit breaker Type (B)
1. Air Magnetic
2. Vacuum
3. Bulk Oil
4. Air Blast
5. "Puffer" Type SF-6
6. All SF-6 other then "Puffer"
7. Other

Normal Maintenance Cycle (K)
1. 0-12 months
2. 12-24 months
3. Over 24 months
4. No preventive maintenance

Maintenance Quality (L)
Your estimate of Preventive Maintenance Quality:
1. Excellent
2. Fair
3. Poor
4. None

Failed Unit Form

Failure Discovered (B)
1. During Routine Testing/ Maintenance
2. During Normal Operation
3. Other

Failure Initiating Cause (C)
1. Transient overvoltage - such as lightning, switching surges, or system faults.
2. Insulation Breakdown.
3. Mechanical burnout, friction, or seizing of moving parts.
4. Mechanical breakdown - such as cracking, loosening, abrading, or deforming of static or structural parts.
5. Physical damage or shorting from outside source - such as vehicular accident.
6. Electrical fault or malfunction.
7. Malfunction of protective relay or tripping device.
8. Other auxiliary device Malfunction.
9. Low, or no, auxiliary voltage - for circuits such as air compressors, and SF-6 heaters.
10. Other

Failure Contributing Cause (D)
1. Overload - persistent
2. Extreme hear (ambient temperature if known ____ deg. C)
3. Extreme Cold (ambient temperature if known ____ deg. C)
4. Severe weather - such as wind, rain, snow, or sleet.
5. Abnormal moisture.
6. Aggressive chemicals.
7. Dust, salt spray, or other contaminant exposure.
8. Normal deterioration from age.
9. Lubricant loss, or deficiency.
10. Improper operating or test procedure.
11. Tripping source deficient.
12. Lack or preventive maintenance.
13. Other

Suspected Failure Responsibility (E)
1. Defective component
2. Improper handling/shipping
3. Poor installation/testing
4. Inadequate maintenance
5. Improper operation
6. Improper application
7. Inadequate physical protection
8. Outside agency (such as vehicular accident)
9. Other
10. Unknown

Failure Mode (F)
1. Failed to close on command
2. Failed to close and latch
3. Failed to open on command
4. Closes without command
5. Opens without command
6. Failed to break current when opened
7. Damaged while successfully opening
8. Damaged while closing
9. Failed to carry current
10. Fault to ground, or phase to phase (not while opening or closing)
11. Fault across open contacts (not while opening or closing)
12. Loss of vacuum (for vacuum breakers)
13. Other failure requiring removal from service within 30 minutes
14. Other failure not requiring immediate removal from service
15. Unknown

Months Since Last Maintenance (G)
1. 0 - 12 months
2. 12 - 24 months
3. Over 24 months
4. No preventive maintenance

Repair Urgency (H)
1. Working round-the-clock
2. Normal working hours
3. Low priority

Repair Or Replace (J)
1. Repaired failed component in place or sent out for repair
2. Replaced failed unit with spare
3. Other

REFERENCES

[1] ANSI/IEEE Standard 493-1980, "IEEE Recommended Practice For Design of Reliable Industrial and Commercial Power Systems".

