Annex P

Survey Results of Low-Voltage Breakers as Found During Maintenance Testing

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Survey Results of Low Voltage Circuit Breakers as Found During Maintenance Testing

Working Group Report

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Abstract **- The Power Systems Reliability Subcommittee strives to maintain current reliability data on major electrical equipment to assist the industry in accomplishing realistic and meaningful reliability studies. This paper presents results of a low voltage circuit breaker reliability survey achieved through use of available results from testing during preventive maintenance. A substantial number of test results were obtained to allow credible results for a few different circuit breaker categories. A similar set of results was published in a paper[1] for the 1990 Industry Applications Society Conference. Most of these results have been incorporated into this new expanded effort.**

INTRODUCTION

Results of a low voltage circuit breaker reliability survey, obtained from circuit breaker preventive maintenance tests are presented here. The results show differences between various categories and what components failed, allowing the reader to judge with some degree of confidence, the weaknesses and strengths of the circuit breakers. Since the results are taken from circuit breaker tests, failure rate as a function of time was not possible. However, because of the nature of the operation of this equipment type, these forms of data and results are of value since often a failure or pending failure is not evident until a test is conducted.

In keeping with the policy of the Power Systems Reliability Subcommittee, survey results of this type do not identify manufacturers, do not promote any types or designs nor are the results intended to draw definite conclusions. This is left to the reader.

The following tables reflect available data from the tests, but only where sufficient data were available to present credible results (in the judgment of this working group).

GENERAL

Certain categories were possible to present, as evidenced in the tables to follow, and some comment is beneficial here in understanding the results. Many tests described certain circuit breakers as being in "new" condition or appearing "new". These were broken out allowing comparison to "old" circuit breakers or those not identified as in "new" condition. Some circuit breakers were tested more than once. Number of tests are shown and were counted separately if approximately 3 years or more apart. It is important to remember the results here are taken from tests that did not identify service conditions, age, or time of use. The tables below show number of tests and also number of circuit breakers to allow evaluation based on either. The failure modes available from the tests are defined as follows.

Trip Unit : failed to operate - repaired or replaced (Note: where calibration

	could not be corrected by readjustment and required replacement, a trip unit failure was counted)
Trip Calibration :	not able to trip within specified current and time range -required readjustment
Mechanical :	springs, arms, levers, hardened lubricant, etc. - repaired or replaced
Power Contacts :	alignment, incorrect pressure, pitted, etc. - repaired or replaced
Arc Chutes :	chipped, cracked, burned, etc. - repaired or replaced
Auxiliary Device :	auxiliary contacts, indicators, pushbuttons, etc. - repaired or replaced

OVERALL SUMMARY (TABLE 1)

Table 1 shows all circuit breakers tested and what failed during a test. The trip unit and trip calibration were the highest in failures, the percentage of failures being 2 or more times that of other failure modes.

TABLE 1

Total No. Bkrs	1174	
Total No. Tests	1989	
Total No. Failures at Test	294	
	No. of Flr's	% of Tests
Failed Component:		
Trip Unit	109	5.5
Trip Calibration	84	4.4
Mechanical	45	2.3
Power Contacts	44	2.2
Arc Chutes	12	0.6
Auxiliary Device	10	0.5
Total No. Failed Components	*304	15.3

* 10 circuit breakers had 2 failed components during one test

SOLID STATE TRIP UNITS VS ELECTROMECHANICAL TRIP UNITS - (TABLE 2)

Table 2 compares solid state (S/S) trip units to electromechanical (EM) type. Results show the EM breaker types with a higher percentage of failures (or unacceptable operation) of all components. As some would predict, the EM trip units experienced substantially more failures than the S/S type, approximately twice the percentage. Since some circuit breakers were described in the test results as in "new" condition, these have been broken out to show any influence this condition may have had on the failures. There was no test data clearly showing EM type as "new", so it can be assumed that none of these appeared in "new" condition. The results show that the "new" S/S type, although showing some expected influence on the results, if broken out separately, would still not change this observation of EM types showing a higher percentage of failures. Another observation is that for all circuit breakers with S/S trip types, there is a more even distribution of percentage of failures over the different failure modes than for E/M types which clearly have the highest percentage of failures associated with the trip units.

TABLE 2

Trip Unit Type	All EM		All S/S		New S/S	
Total No. of Bkrs	662		512		99	
Total No. of Tests	1054		935		176	
Failed Component	# of Flr's	% of Tests	# of Flr's	% of Tests	# of Flr's	% of Tests
Trip Unit	81	7.7	28	3.0	*2	1.1
Trip Calibration	60	5.7	24	2.6	*0	0.0
Mechanical	26	2.5	19	2.0	*4	2.3
Power Contacts	25	2.4	19	2.0	*5	2.8
Arc Chutes	*6	0.6	*6	0.6	*0	0.0
Auxiliary Device	*6	0.6	*4	0.4	*0	0.0
Total No. Failures	204	19.4	100	10.7	11	6.2

* Small sample size - less than 8 failures

SOLID STATE vs. ELECTROMECHANICAL ACCORDING TO FRAME SIZE (TABLE 3)

Table 3 shows how circuit breakers with S/S and EM trip units compare according to frame size. The 600 amp and 800 amp frame sizes are combined since very little difference is expected in applications. Larger frame sizes include 4000 amp, but the total number breakers and tests warranted combining all sizes 1600 amp and above. Results show a significant difference in percentage of failures between the smaller and larger frame sizes for circuit breakers with EM trip units, with the larger frame sizes higher than that of the smaller sizes. Frame size shows less effect on the difference between large and small circuit breakers with S/S trip types. EM trip units still show an obviously higher percentage of failures when compared to S/S type.

TABLE 3

Frame Size	600 A & 800 A				1600 A & Above			
Trip Unit Type	EM		S/S		EM		S/S	
No. of Breakers	464		380		198		132	
No. of Tests	842		778		212		157	
Failed Component	# of Flr's	% of Tests	# of Flr's	% of Tests	# of Flr's	% of Tests	# of Flr's	%of Tests
Trip Unit	50	5.9	20	2.6	31	4.6	8	5.1
Trip Calibration	41	4.9	22	2.8	19	9.0	*2	1.3
Mechanical	17	2.0	16	2.1	*6	2.8	*3	1.9
Power Contacts	16	1.9	19	2.4	*6	2.8	*0	0.0
Arc Chutes	*6	0.7	*4	0.5	*0	0.0	*0	0.0
Auxiliary Device	*2	0.2	*3	0.4	*2	0.9	*1	0.6
Total No. Failures	132	15.7	84	10.8	64	30.2	14	8.9

* Small sample size - less than 8 failures

SOLID STATE vs ELECTROMECHANICAL TRIP CALIBRATION FAILURES (TABLE 4)

Table 4 shows the failure relationship between the long time, short time and instantaneous settings of trip units. Some circuit breakers had more than one time setting out of calibration, evidenced by the total exceeding the total of trip calibration failures in tables above. Some circuit breakers did not have all 3 time settings available, but practically all had instantaneous settings with the exception of a few. The results show no calibration failures for the instantaneous settings for S/S trip units.

TABLE 4

Trip Unit Type	All EM		All S/S	
Total No. of Bkrs	662		512	
Total No. of Tests	1054		935	
Trip Calib. Failure	# of Flr's	% of Tests	# of Flr's	% of Tests
Long Time	45	4.3	14	1.5
Short Time	*1	0.1	11	1.2
Instantaneous	29	2.8	*0	0.0
**Total	75	7.1	25	2.7

* Small sample size - less than 8 failures
** Some circuit breakers had more than one time setting out of calibration

OBSERVATIONS/CONCLUSIONS

A significant observation from the results of this survey is that, for all circuit breakers, the percent of unacceptable operations of EM trip units were more than twice those with S/S trip units. This included both failure of the trip unit to operate and failure due to calibration.

EM trip units for circuit breakers rated 1600 amp and above, combined, experienced more than twice the percent of unacceptable operations as those rated 600 amp and 800 amp, combined. Again, this included both failure of the trip unit to operate and failure due to calibration.

For all circuit breakers, both percent of unacceptable operation of trip units and calibration were much higher than the other failure modes. Mechanical operation failures and power contact failures experienced the same percentage for both EM and S/S type circuit breakers.

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REFERENCES

[1] "Maintaining the Integrity of a Changing Power System", by M.J. Kornblit, IEEE Industry Applications Society, Oct. 7 - 12, 1990, Seattle, IEEE Catalog No. 90CH2935-9, pp 1357 - 1362

