Circuit Breaker Timing and Travel Analysis

TR-112783

Final Report, May 1999

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REPORT SUMMARY

This guidance provides nuclear electric utilities with some basic information and insight into the use, benefits, and limitations of circuit breaker timing and travel analysis, as applied to low and medium voltage circuit breakers.

Background

The nuclear power industry's circuit breaker user groups, under the sponsorship of EPRI-NMAC, are involved in the development of circuit breaker maintenance guidance documents for industry use. In the course of this development, it was apparent that it would be beneficial for the groups to collectively address timing and travel analysis. By collectively addressing this type of testing, the industry could establish a position on the use, benefits, and limitations of time and travel analysis. This effort was designed to develop a technical basis for the use of timing and travel testing in proper maintenance, such that utilities could enhance and justify their specific site procedures. By providing guidance that contains the collective experience of the user groups, utilities have established a platform from which the entire industry can justify and improve maintenance programs for low and medium voltage circuit breakers.

Objectives

- To provide nuclear electric utilities with some basic information and insight into the use, benefits, and limitations of circuit breaker timing and travel analysis, as applied to low and medium voltage circuit breakers.

- To provide a consensus among utility personnel, considering the manufacturers' recommendations and the unique application of these circuit breakers within our industry.

Approach

This document was developed by a utility working group, under the management of EPRI-NMAC. The utility working group (1) reviewed utility procedures and vendor manuals; (2) obtained input from utility personnel, manufacturers and other organizations. After initial development, the draft was provided to a larger working group and manufacturers for review and comment. Representatives from GE, ABB,

and Westinghouse Nuclear Service Division (NSD) reviewed the document and gave comments. Laboratory testing of circuit breakers was not performed, as this was not deemed necessary to accomplish the objectives of this effort.

This guidance is applicable to both low (480/600 volt) and medium (4160/15,000 volt) voltage circuit breakers.

Results

This guidance defines timing and travel tests, discusses test equipment and set-up, and test variables to consider, denotes typical test criteria, discusses the information gleaned from testing, and provides specific user group and manufacturer recommendations. In most cases, specific manufacturer recommendations have never before been documented. Based on comments from utility personnel, the most valuable result to come from development of this guidance is that this information has been collected and placed into a single, easily accessible documented source.

The general consensus within the industry is that circuit breaker timing and travel analysis (tests) provides some indication of the condition of specific circuit breaker subcomponents, but does not provide a comprehensive assessment of the overall condition of a circuit breaker. Trending of timing test data is not recommended by any of the three major circuit breaker manufacturers (ABB, GE or Westinghouse) and is not generally performed. Timing tests are usually considered a pass or fail (go/no-go) test.

EPRI Perspective

This effort is a collaborative industry effort with numerous utility and non-utility personnel providing their experience and knowledge. This document was written and designed to be used in conjunction with the circuit breaker maintenance guide series (EPRI NP-7410).

This is considered to be a living document. The nuclear industry's circuit breaker user groups, along with EPRI-NMAC, are tasked with providing an annual forum or mechanism to incorporate additions or changes to this guidance. It is expected that plant personnel and the circuit breaker user groups will continually review the contents.

Keywords

Control equipment
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PREFACE

This document was developed by a committee comprised of both utility and non-utility personnel, under the sponsorship of EPRI's Nuclear Maintenance Applications Center. The committee does not view this document as an exhaustive investigation. More definitive positions on the use, benefits, and limitations of timing and travel analysis could come in time, but to develop such a position would require a thorough engineering analysis or testing program. A detailed engineering or testing study has not been performed at this time.

This document is intended to be a living document. Changes to it can be made as new data or information arise.

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1

DEFINING TIMING AND TRAVEL TESTING

The purpose of this paper is to provide nuclear electric utilities with some basic information and insight into the use, benefits, and limitations of circuit breaker timing and travel analysis as applied to low and medium voltage circuit breakers.

1.1 Defining Timing Tests

The purpose of a timing test is to determine the response time during the opening and/or closing operation of a circuit breaker. The closing time is the time that elapses between initiating an electrical close (control) signal and the instant the arcing contacts touch. The opening time is the time that elapses between initiating an electrical trip (control) signal and the instant the arcing contacts separate. When acceptance criteria is provided, it is usually provided in milliseconds or cycles. After the coil and latch function, the resultant release of spring energy will move the main and arcing contacts. The open or close time of a circuit breaker includes the:

- Coil response time
- Mechanical response time (including time for the mechanical latches and linkages to physically trip or close the breaker)
- Time it takes the arcing contacts to travel the distance to either separate (during tripping) or touch (during closing)

See Figures 1-1 and 1-2 for typical closing and opening travel test data.

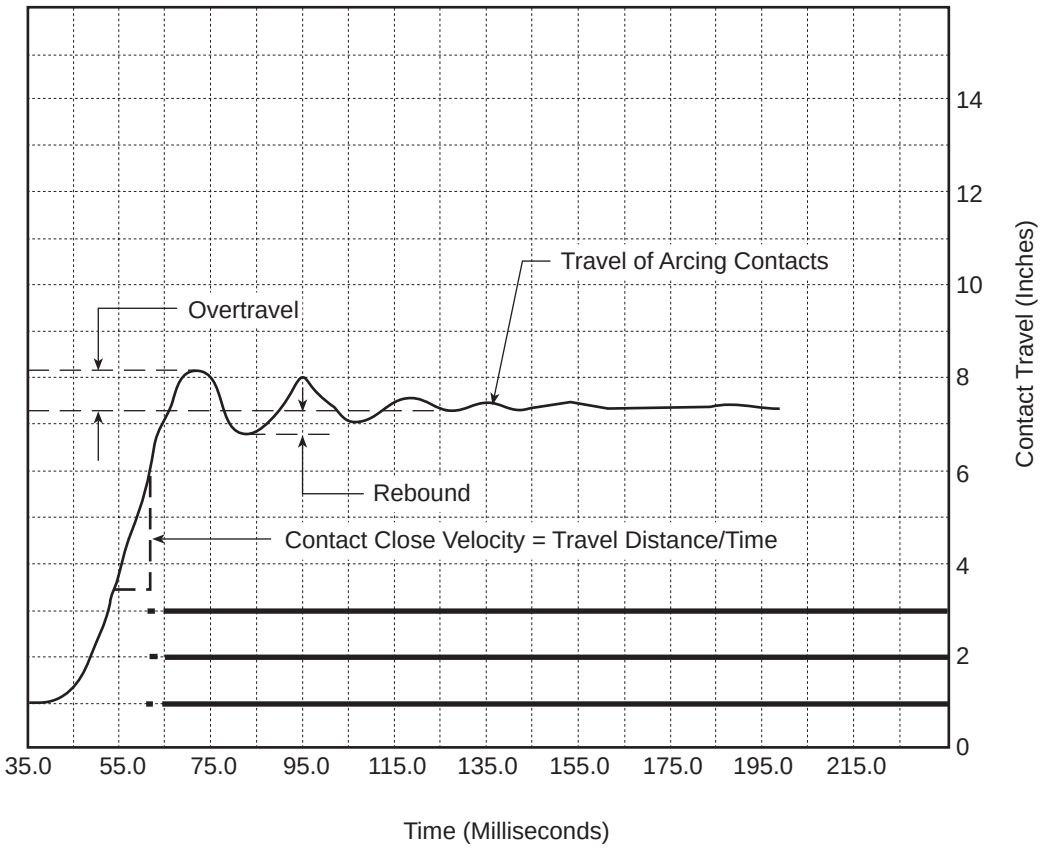
The timing test requires only electrical connections to the circuit breaker, whereas the travel test requires both electrical connections and a motion transducer attached to the arcing contacts.

1.2 Defining Travel Tests

Travel tests, in addition to providing timing values, also show actuation of the coil, velocity (speed of travel) (ft/sec or inches/sec) of the contacts, travel distance (stroke), penetration of the contacts, rebound of the movable contacts, and contacts

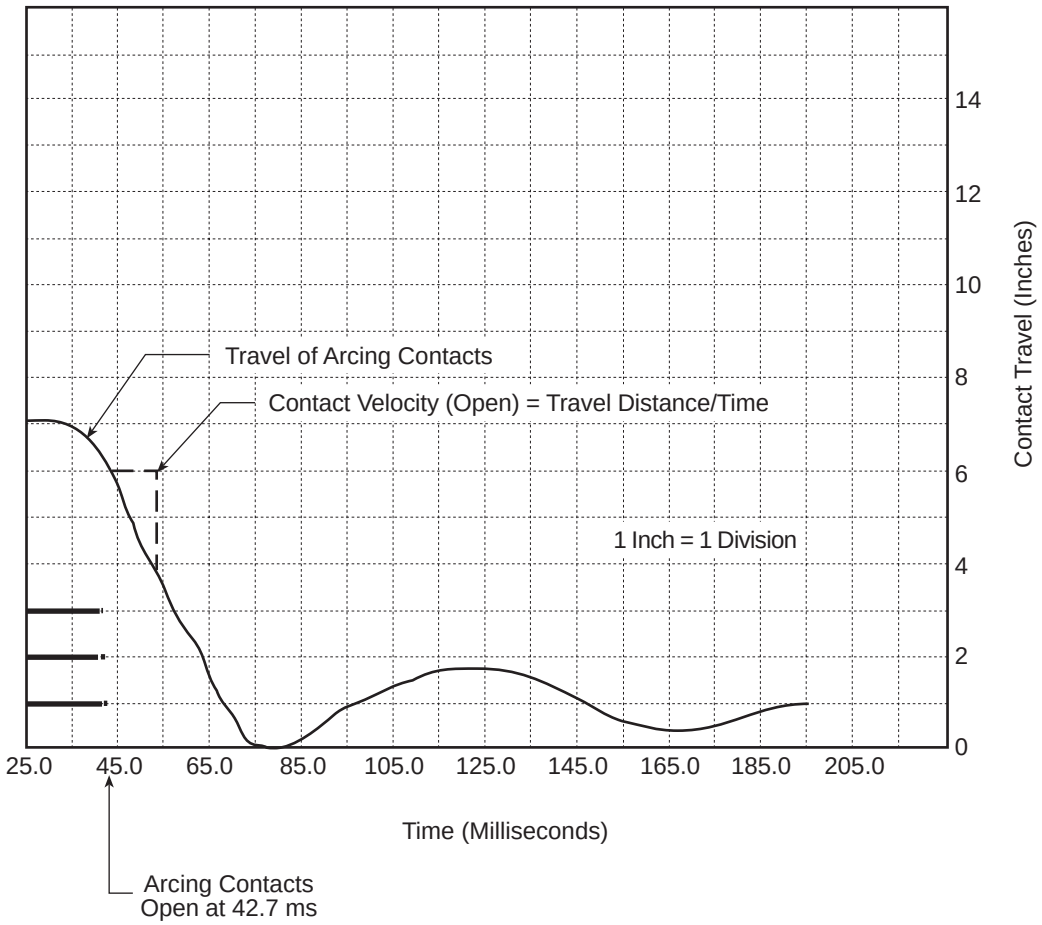
overtravel / undertravel. Typical acceptance criteria is provided in units of feet / second (ft / sec).

Circuit breaker contact travel speed during the arc period is critical to the proper arc cessation should the breaker trip on fault or open under load. Contact timing cannot be directly related to mechanism velocity because timing includes the time for coil energization. Mechanism velocity is measured after coil energization and is a linear value of contact movement as driven by the springs.



PARAMETERS	CLOSE 1
Close Time A	61.4 ms
Close Time B	62.0 ms
Close Time C	61.6 ms
Close Time	62.0 ms
Diff. A-B-C	0.6 ms
Close Speed	27.9 f/s
Stroke	6.35 inch
Penetr. A	1.42 inch
Penetr. B	1.22 inch
Penetr. C	1.35 inch
Overtrav.	0.81 inch
Rebound	0.63 inch

Figure 1-1
Close Operation
Typical Circuit Breaker Time and Travel Analysis Data from a Programma® Circuit Breaker Analyzer Performed on a Magne-Blast Circuit Breaker (courtesy of General Electric Nuclear Service Division)



PARAMETERS	OPEN 1
Open Time A	42.7 ms
Open Time B	42.1 ms
Open Time C	42.0 ms
Open Time	42.7 ms
Diff. A-B-C	0.7 ms
Open Speed	16.4 f/s
Stroke	6.06 inch
Penetr. A	0.98 inch
Penetr. B	0.86 inch
Penetr. C	0.84 inch
Undertrav.	1.11 inch
Rebound	0.75 inch

Figure 1-2
Open Operation
Typical Circuit Breaker Time and Travel Analysis Data from a Programma® Circuit Breaker Analyzer Performed on a Magne-Blast Circuit Breaker (courtesy of General Electric Nuclear Service Division)

2

INFORMATION PROVIDED BY TIMING AND TRAVEL TESTS

It is important to note that timing and travel tests provide some indication of the condition of a few specific circuit breaker subcomponents (based on manufacturer and model), but do not provide a comprehensive assessment of the overall condition of a circuit breaker.

Maintenance personnel should not be lured into a potential false sense of security if a circuit breaker simply meets the specification for a time or travel test.

Timing and travel tests should be considered one of the tools available to build a circuit breaker maintenance program. Other tests and inspections are a necessary part of a comprehensive program. Timing and travel tests might or might not be necessary, depending on the specific maintenance program and other factors.

The timing test can provide information on the factors outlined in sections 2.1 through 2.5.

2.1 Response Time

The timing test is useful when evaluating:

- Fast (or dead) bus transfer (one bus will trip and another will close in the required time to pick up the load)
- Response time testing (for technical specifications)
- Protective device coordination (that is, breaker meets design open and closing times)

2.2 Mechanical Binding

The timing test can indicate if there is potential mechanical binding of the open/close latch and coil plungers. If open and closing times are excessive, this might indicate bent,

broken, worn, misaligned, or seized subcomponents in the coil and latch function. The latches and coil plunger can be physically checked for freedom of movement.

2.3 Friction Problems

There is general consensus that, depending on the manufacturer and model, timing tests can potentially indicate gross friction problems on specific subcomponents within a circuit breaker.

"As-found" timing tests can be performed prior to any maintenance pre-conditioning of the mechanism. There are, however, other preventive maintenance (PM) tasks that are better indicators of binding and lubrication problems within the circuit breaker. These tasks are discussed in more detail within the specific circuit breaker maintenance guidance documents being developed by the circuit breaker users groups.

2.4 Function of Close/Trip Coils

The timing test provides information on the ability of the close and trip coils and associated latches to release the stored energy. A visual exam and physical exam for free movement of the plungers can determine the condition of the coils.

Timing tests provide an objective measured value, which can be compared to the manufacturer's timing specification, as an alternative to subjective physical and visual examination of the coils and latches.

The travel test, in addition to providing the same information as the timing test, also provides information on the following:

- Overtravel / Undertravel of the arcing contacts
- Rebound of the arcing contacts
- Opening and closing velocity
- Travel distance
- Penetration

Refer to Figures 1-1 and 1-2 for graphical definitions of overtravel, undertravel, rebound, travel distance, and penetration.

2.5 Lubricant Condition

The committee developing this document does not feel that enough information exists at this time to make any statements regarding information on lubricant condition obtained from timing or travel tests. To the best knowledge of the committee, a detailed engineering or testing study has not been performed to definitively determine if or how timing or travel testing can indicate lubricant condition.

3

PERFORMING TIMING AND TRAVEL TESTS

3.1 Test Equipment

A circuit breaker timing test can be performed with a high speed recorder or digital timer capable of reading 0-150 milliseconds, and dc power supply. See Figure 3-1 for a typical timing test arrangement.

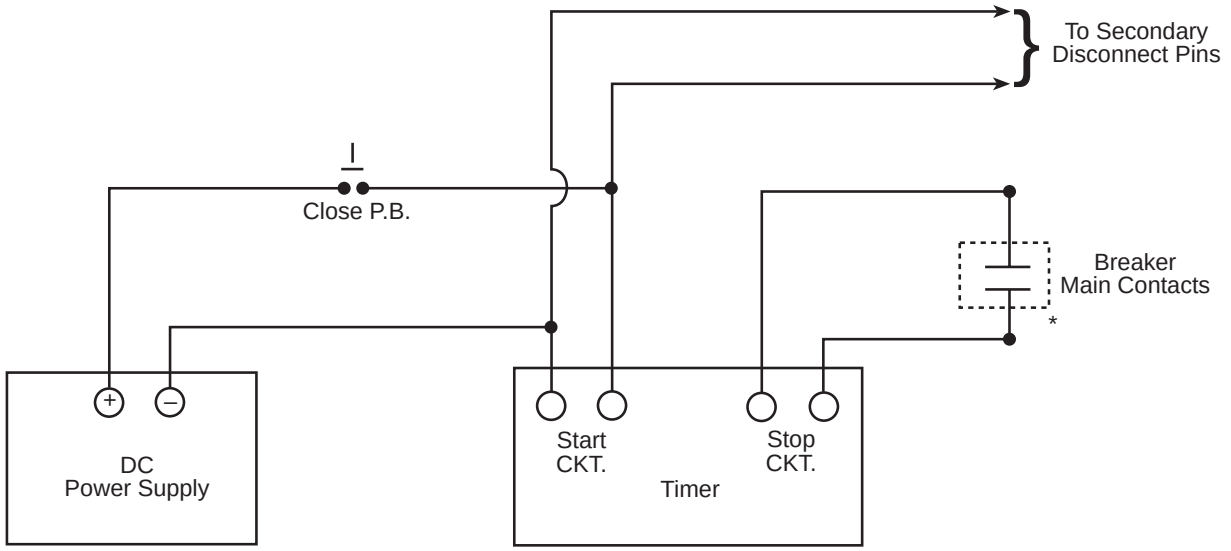
For time and travel analysis testing, a high speed recorder or digital timer is needed, along with a motion transducer. The motion transducer records the travel and velocity of the arcing contacts. See Figure 3-2 for a typical time and travel analysis arrangement for a Magne-Blast circuit breaker.

Some time and travel analyzer test equipment manufacturer's include Programma® and Vanguard®. These manufacturers utilize a transducer to convert mechanical motion to an electrical signal.

3.2 Test Variables

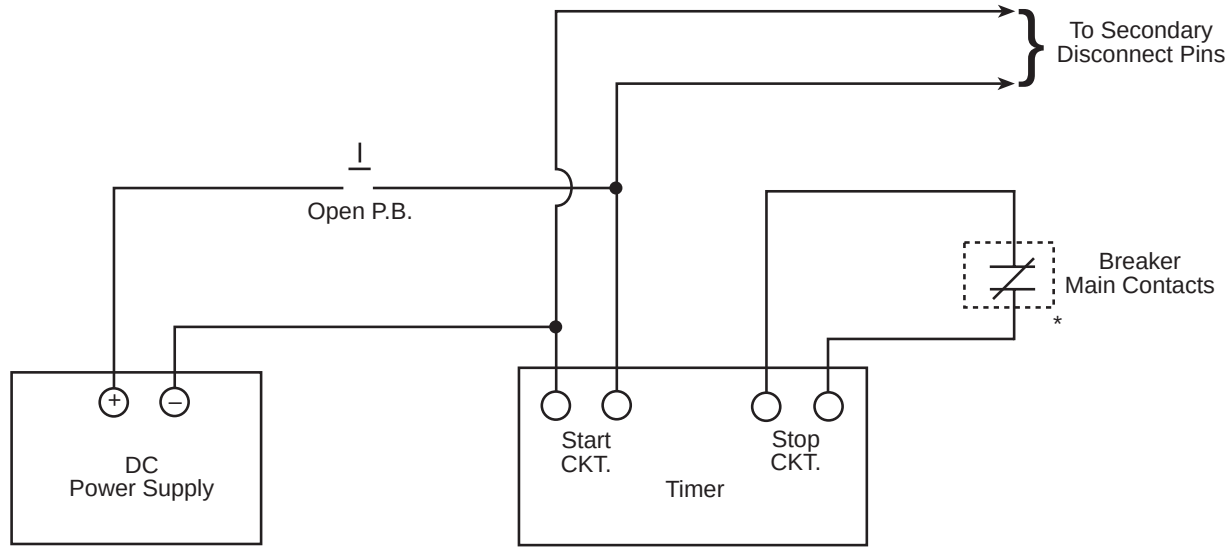
The following should be considered when performing timing and travel tests:

- Large variances in control (power supply) voltages can affect opening and closing times [1].
- Cycling of a circuit breaker, just prior to performing a timing test, can affect the results of a timing and travel test. "As-found" timing tests can be performed prior to performing any maintenance on the mechanism.
- Due to power supplies and test equipment (consistency of voltage source) [2], repetitiveness of timing data has been questioned by some utility personnel. Power supply equipment does exist, however, that will perform this test satisfactorily.
- The tests should be run at nominal voltage. The power supply should be capable of producing full coil current without a voltage drop.



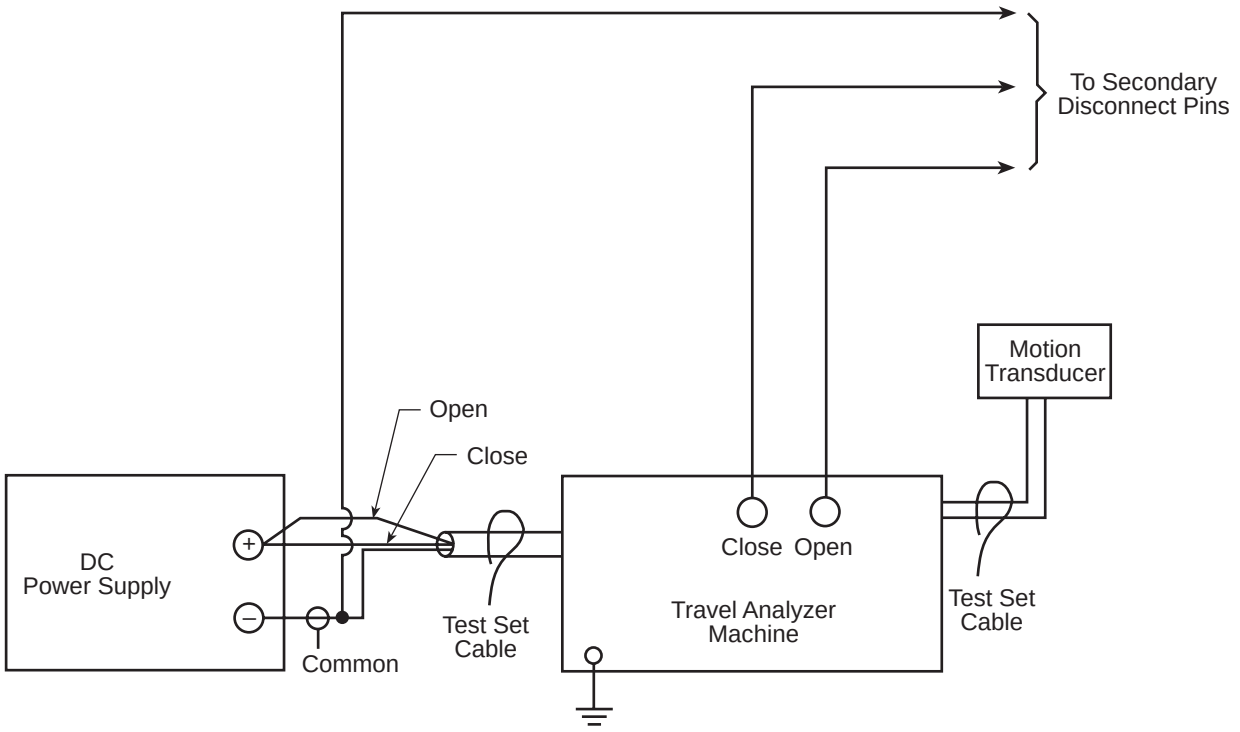
Close Time Test

* Note: Connect timer stop leads to the primary disconnects.



Open Time Test

Figure 3-1
Typical Open and Close Timing Test Set-Up (taken from *Guidance for Routine Preventive Maintenance for Magne-Blast Circuit Breakers*)



Notes: 1) Motion transducer is mounted on the breaker.

2) Close and open signal to the breaker is controlled by the travel analyzer machine.

Figure 3-2
Typical Open and Close Timing and Travel Test Set-Up

4

MANUFACTURERS' RECOMMENDATIONS

The following identifies recommendations from each of the major circuit breaker manufacturers. To reduce confusion and increase accuracy, this document attempts to distinguish between documented recommendations, current, potentially undocumented recommendations, and actual shop practices of the manufacturer.

4.1 GE Nuclear Energy

4.1.1 Magne-Blast Circuit Breakers

4.1.1.1 Literature

Timing and travel tests are not expressly recommended by any GE technical manual or any known service advice letter (SAL). However, travel test acceptance criteria (travel velocity) is specified within GE manuals for specific breakers.

The following statement is taken from GEK-7320F, page 14, as a part of GE's discussion for opening and closing speed: *"Proper servicing and lubrication of the breaker and its operating mechanism should maintain these speeds and no adjustment is provided"*.

4.1.1.2 GE's Comments

GE's position is that if proper maintenance is performed on a circuit breaker, then timing or travel tests are not required. Proper maintenance is maintenance that is recommended within GE instruction manuals and within other GE literature such as SALs and SILs. GE does recommend that travel tests be performed after circuit breaker overhaul (refurbishment). GE has suggested that timing and travel tests could be used as a final check, to provide increased assurance that the breaker is not degraded in any way.

4.1.1.3 Shop Practices

The travel test is usually performed by GE when a Magne-Blast breaker is sent to a GE service shop for repairs or overhaul (refurbishment).

4.1.1.4 Trending

At this particular time, timing or travel test values have not been established as trendable, nor has it been established that there is benefit in trending timing / travel data. GE has suggested that trending of timing and velocity can be valuable and they are undertaking a study to prove or disprove this statement. This study is ongoing and is sponsored by the BWR (Boiling Water Reactor) Owners Group.

4.1.2 AK/AKR - Low Voltage Circuit Breakers

4.1.2.1 Literature

There are no documented recommendations from GE for performing timing or travel tests on low voltage circuit breakers.

4.1.2.2 GE Comments

There are other tests that are better than timing tests, which can be used to provide an indication of circuit breaker reliability. Unpublished operating times do exist but are used more for circuit breaker application. The source of these times is not currently identified.

4.1.2.3 Shop Practices

GE does perform timing tests on all AK / AKR circuit breakers that are repaired or overhauled in their service shops. The timing data is compared to industry established numbers, such as those for reactor trip circuit breakers. These timing numbers do not represent GE acceptance criteria.

4.1.2.4 Trending

GE does not consider trending of low voltage circuit breaker timing data to be valuable.

4.2 ABB T&D and ABB Service

4.2.1 HK Breakers

4.2.1.1 Literature - Timing Test

“(A timing test) should be run before and after the bridge pivot pressure adjustment. Recommended as a pertinent periodic test to evaluate breaker condition.” [3](ABB MS 3.2.1.9-1)

Timing test criteria are provided within ABB Installation and Maintenance Instruction Bulletins (IBs).

4.2.1.2 ABB Service Comments on Timing Tests

ABB Service does recommend timing tests as a periodic, routine preventive maintenance task [4].

According to ABB Service, circuit *"breaker condition"*, as referenced in the above maintenance surveillance (MS) statement, pertains to selected breaker subcomponents and does not provide a complete assessment of the circuit breaker [4].

4.2.1.3 Literature - Travel Test

ABB T&D manuals and literature do not recommend travel testing for periodic maintenance or overhaul [4].

4.2.1.4 ABB Service Comments on Travel Tests

ABB Service does not require that travel testing be performed on HK breakers. ABB Service has no significant experience with travel testing and has not collected or analyzed travel test data [4].

4.2.1.5 Shop Practices on Timing Tests

Timing tests are performed within ABB Service shops on all circuit breakers (repair and overhaul). Both as-found and as-left tests are performed [4].

4.2.1.6 Shop Practices on Travel Tests

Travel testing within ABB Service shops is not standard practice and is not required. Neither ABB T&D nor ABB Service has acceptance criteria for travel testing of HK circuit breakers [4].

4.2.1.7 Comments from ABB Service

If a circuit breaker has been overhauled, ABB Service does consider travel testing to be a good idea [4].

4.2.1.8 Trending

ABB Service does not recommend trending timing test data [4].

4.2.1.9 Reduced Voltage Testing

ABB T&D's recommendations, per ABB MS 3.2.1.9-1, page 8, states "During servicing it is desirable to verify breaker operability. It is recommended that this be done at the minimum expected control voltage level (typically 80% of nominal)."

ABB T&D does not require minimum (reduced) voltage timing tests. The ABB timing specifications are based on 125 Vdc (control voltage) [4].

4.2.2 K-Line Breakers

ABB Service does not find value in timing (or travel testing) of low voltage breakers and therefore, does not require that these tests be performed [4].

4.3 Westinghouse Nuclear Service Division (NSD)

4.3.1 DHP Circuit Breakers

4.3.1.1 Literature

Following are quotes from various documents received from Westinghouse:

"Westinghouse does not recommend the timing test as a standard preventative maintenance task" [5].

"During normal maintenance check for sluggishness, if needed, perform a timing test" [6].

"If a DHP breaker seems sluggish, a timing test should be performed" [7].

"During normal maintenance check for sluggishness, if needed, perform a timing test. If slow, readjust, perform contact maintenance. If still slow, replace the springs. If still slow, refurbish through the OEM" [5].

4.3.1.2 Information Obtained (Lubrication)

“Westinghouse only uses the Travel Test data for the velocity of the DHP breaker” [5].

4.3.1.3 Trending

“Westinghouse NSD considers circuit breaker timing a “go/no go” test and should not be trended” [5].

4.3.1.4 Westinghouse NSD Comments

"Breaker lubrication condition can be indicated by breaker operation and is related to the forces required to trip the breaker. However, timing tests are not recommended" [8].

4.3.1.5 Overhaul

Westinghouse NSD does recommend time and travel analysis on any new or refurbished (overhauled) circuit breaker. Quoting from the Westinghouse letter of December 12, 1997: “*All new and remanufactured breakers should be subject to both the opening timing tests (in cycles) and the velocity timing test performed with a travel recorder"* [7,6].

4.4 DB/DS Circuit Breakers

4.4.1 Timing Tests

Westinghouse does not recommend the need to conduct timing tests for DB and DS breakers [8].

Timing tests are not recommended [8].

Westinghouse has not developed timing test criteria for DB and DS breakers [8].

4.4.2 Trending

There is no basis developed for trending timing test results for DB and DS breakers [8].

4.4.3 Lubrication and Reduced Voltage Testing

Breaker lubrication condition can be indicated by breaker operation and is related to the forces required to trip the breaker [8].

4.4.4 Reduced Voltage Testing

Westinghouse recommends reduced voltage testing to determine breaker functionality and lubricant condition [8].

5

USERS GROUP GUIDANCE

5.1 Magne-Blast

5.1.1 Documented Guidance

The timing and travel tests do appear in the document entitled *Guidance for Routine Preventive Maintenance for Magne-Blast Circuit Breakers*, February, 1998. The following is an excerpt from that document:

"Performance of this test is at the discretion of each plant at this time. However, each plant should give serious consideration in performing this test or the travel test . . ."

5.2 ABB HK

5.2.1 Documented Guidance

The timing test does appear in the draft document entitled, *Guidance for Routine Preventive Maintenance for ABB HK Circuit Breakers*, March 11, 1998. The justification cited for including this test is the vendor manual's recommendation. The travel test does not appear in the document.

The guidance states: "This test is useful to determine if there are any binding problems with the mechanism. IB 6.2.1.7D and IB 6.2.2.7-1G recommends performing timing tests after a number of operations, based on breaker type, or after a change in bridge pivot adjustment."

The timing test is one factor, but not the only or most significant factor, in determining the condition of the bridge pivot.

It should be noted that several members of the ABB HK Working Group feel that timing tests can indicate mechanical binding but are actually poor indicators of lubricant condition. They feel that timing tests do not indicate the quality or quantity of circuit breaker lubrication, nor do they provide a complete analysis of the condition of the bridge pivot point. When the open or close signal is received (the coil is energized) and

the stored energy is released, the breaker will open or close, even in the case of inadequate, contaminated, or excessive lubricant. The time it takes for the breaker to open or close does not indicate that a degraded lubricant condition is the problem.

There are other members of the users groups, however, who feel that timing tests are a good indicator of lubricant condition.

5.2.2 Reduced Voltage

ABB T&D's minimum and maximum specifications are based upon 125 Vdc control voltage. ABB does not provide specifications for control voltages other than nominal. ABB does not require minimum (reduced) voltage timing tests.

5.3 Westinghouse DHP

5.3.1 Guidance for Routine Preventive Maintenance for DHP Circuit Breakers

The timing and travel tests do not appear in the draft document entitled *Guidance for Routine Preventive Maintenance for Westinghouse DHP Circuit Breakers,* January 22, 1998.

5.3.2 Overhaul

The users group does recommend time and travel analysis on any new or refurbished (overhauled) circuit breaker [6].

6

CONCLUSIONS

6.1 Comprehensive Assessment

There is general consensus within the industry that circuit breaker timing and travel analysis tests provide some indication of the condition of specific circuit breaker subcomponents (based on manufacturer and model), but do not provide a comprehensive assessment of the overall condition of a circuit breaker.

6.2 Trending

Trending of timing test data by analyzing or plotting data in order to predict a degraded condition, failure, or out-of-specification condition, is not recommended by any of the three major circuit breaker manufacturers (ABB, GE, or Westinghouse). Trending of time and travel test data to identify a time-based statistically detectable change is generally not performed.

The primary objective when performing a timing test is to determine if the data obtained is within specification. The timing test is usually considered a pass or fail (go / no-go) test.

7

REDUCED VOLTAGE TESTING AS APPLIED TO TIMING/TRAVEL TESTS

The purpose of this section is to discuss the difference between timing / travel analysis and reduced voltage. A discussion on reduced voltage testing is beyond the scope of this document. *(Note: Another paper is planned that will discuss reduced voltage testing. Utility input is welcomed and encouraged.)*

The purpose of a reduced voltage test is to determine if the circuit breaker will operate as designed under a reduced voltage condition. The purpose of a timing test is to determine the response (open and close) time of a circuit breaker. For circuit breaker operability, the question is: *did (or would have) the circuit breaker perform its intended design function (trip open or close) at the minimum operating voltage, and within applicable specifications (source and load-based specs apply)?*[5]

If reduced voltage testing is performed, timing (and travel) tests can be done simultaneously, but it is not necessary that they be done simultaneously.

It has been suggested that there can be benefits in performing timing tests under reduced voltage conditions. At the present time, however, there is not a clear understanding of the benefits, if any, or the motivation for this type of testing. More research and investigation is needed on this issue.

Note:

Manufacturers test breakers per ANSI requirements, which are focused on manufacturing (acceptance) tests. Manufacturers are only concerned about functionality at low voltage (that is, did the breaker trip or close?). Normal performance specifications are generally applied at nominal voltages.

Licensing and design basis for nuclear utilities are different than ANSI manufacturing specifications as they have a different perspective. Utilities are required to analyze these differences as part of their accident analyses. This should be done as part of the initial design process. For the utilities, ensuring that the breakers meet the ANSI manufacturing criteria should be sufficient, providing the analyses previously performed are adequate.

8

TYPICAL TEST CRITERIA

The test criteria below is typical but is provided for comparative purposes only. Users should contact the manufacturer for proper opening and closing times for their specific circuit breakers.

Circuit Breaker	Test Criteria
ABB HK	Depending on the breaker model, closing times range from 50 to 95 milliseconds, and opening times range from 23 to 42 milliseconds.
Magne-Blast	Opening (trip) times for all sizes of breakers is 50 milliseconds. Closing times for the different size breakers vary as follows: 4.16 kV, 250 MVA closing time = 83 milliseconds 4.16 kV 350 MVA = 100 milliseconds 13.8 kV 750 MVA = 100 milliseconds 13.8 kV 1000 MVA = 116 milliseconds
Westinghouse DHP	Opening: 1.5 - 2.5 cycles or 25-45 milliseconds Closing: 5kV 3.5-7 cycles or 58-117 milliseconds 7.5 / 15 kV: 3.5-9 cycles or 58-150 milliseconds

Note: The values associated with the Westinghouse DHP breaker are for the breaker operating at nominal rated control voltage, for example, at 125 Vdc.

9

REFERENCES

1. Written comments from Don Lukach of Illinois Power's Clinton station: Variances in control (power supply) voltages can affect opening and closing times. Clinton uses 100 volt tests to account for low voltage conditions.

2. Written comments from Don Lukach of Illinois Power's Clinton station: Westinghouse design spec testing used +/- 2 Vdc @ 125 Vdc, Clinton uses +/- 1Vdc.

3. ABB Maintenance Surveillance (MS) 3.2.1.9-1, page 7.

4. Telephone conference call of May 15, 1998 between ABB Service the officers of the ABB Circuit Breaker Users Group, and EPRI-NMAC.

5. Westinghouse (Dale Rygg) E-mail to NMAC (Jim Sharkey) dated May 4, 1998.

6. Conference call between Dale Rygg(Westinghouse), Tom Critchlow (Westinghouse), Jim Sharkey (EPRI-NMAC) , Joe Folta (Susquehanna), Joe Valent (TMI), Paul Merrill (Susquehanna) on March 17, 1998.

7. Westinghouse letter from Dale Rygg (Westinghouse NSD) to Jim Sharkey (EPRI-NMAC) and Bob Crosby (ComEd), dated December 12, 1998.

8. Westinghouse e-mail response to NMAC from Dennis Adomaitis dated 5/11/98.

A

APPENDIX A

Westinghouse DHP Timing Test Procedure

Courtesy of Westinghouse Nuclear Service Division

Subject: DHP Breaker Closing and Opening Time Tests Using Doble FT-2 Power System Timer

The purpose of this letter is to provide the detailed procedures to time the breakers when using the Doble FT-2 Power System Timer.

1. Remove the breaker from its cell. Warning: Prior to removing the breakers from their cells, the user must verify that the breaker's main contacts were first tripped open.

2. Connect the breaker secondary disconnect contact to its mating contact in the cell by use of the test cable. Note that the nominal control voltage must be used.

3. Normally, by performing the previous step, the closing spring is automatically charged. If this did not happen due to site conditions, the spring can manually be charged now.

4. Connect the wires from the START circuit of the FT-2 Power System Timer to the closing release circuit on the terminal block in the breaker cell.

5. Connect the wires from the STOP circuit of the FT-2 Power System Timer to the breaker main contacts of one phase. Flexible copper braid can first be wrapped around the bus bar just behind the finger clusters to provide a better connection for the alligator clips on the wires.

6. Set the START circuit switch of the FT-2 Power System Timer to the contact normally closed position.

7. Set the STOP circuit switch of the FT-2 Power System Timer to the contact normally open position.

8. Set the RANGE selector switch of the FT-2 Power System Timer to the 999 milliseconds position.

9. Set the POWER switch of the FT-2 Power System Timer to ON and activate the reset switch momentarily. Note that the FT-2 Power System Timer should display 3 zeroes, the test buzzer should not sound, and the test light should not be lit.

10. Close the breaker electrically and record the time from the display. The time must be within milliseconds specified for the breaker rating (see Sheet 2).

11. Change the STOP switch of the FT-2 Power System Timer to the contact normally closed position and activate the reset switch. Note the test buzzer will stop sounding, the test light will go out, and the FT-2 Power System Timer will display 3 zeroes.

12. Move the START wires from the closing release circuit on the terminal block in the cell to the trip (opening) circuit on the terminal block.

13. Trip (open) the breaker electrically and record the time from the display. The time must be within milliseconds specified for the breaker rating (see below).

Westinghouse DHP Breaker Timing Tests

Opening:

Measure time from energizing trip coil to parting of breaker arcing contacts at nominal control voltage (for example, 125 Vdc control would be tested at 125 Vdc).

For all ratings: 1.5 to 2.5 cycles on 60 cycle basis or 25 to 42 milliseconds

Closing:

Measure time from energizing spring release coil to touching of arcing contacts at nominal control voltage.

5kV: 3.5 to 7 cycles on 60 cycle basis or 58 to 117 milliseconds

7.5/15 kV: 3.5 to 9 cycles on 60 cycle basis or 58 to 150 milliseconds