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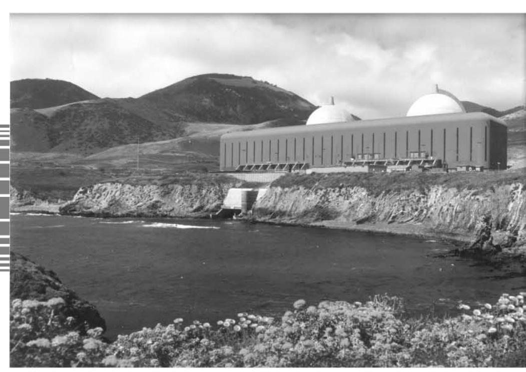
Circuit Breaker Maintenance Programmatic Considerations

1000014



NMAC

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1000014

Technical Evaluation, December 2000

EPRI Project Manager

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ABSTRACT

This document describes circuit breaker maintenance programmatic considerations and includes such topics as

- Program documentation and organizational responsibilities
- Support of equipment's design basis
- Maintenance procedures (preventive, corrective, and overhaul as applicable)
- Established maintenance intervals (frequencies) if maintenance is time-based
- Maintenance history, trending, work control and reporting systems
- Overhaul Strategy
- Use of industry experience
- Personnel qualification and training
- Parts procurement
- Self Assessments

This document is intended for nuclear power plant personnel and is offered for their review and consideration when developing or refining a circuit breaker maintenance program. Although specifically directed to nuclear power plants, the vast majority of the information contained within is also applicable to fossil electric power plants.

This document summarizes the efforts of the nuclear power industry's circuit breaker users groups during the period from 1994 through 1999.

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CONTENTS

Introduction

A circuit breaker maintenance program should be well-defined and include basic elements such as

- Program documentation and organizational responsibilities
- Support of equipment's design basis
- Maintenance procedures (preventive, corrective, and overhaul as applicable)
- Established maintenance intervals (frequencies) if maintenance is time-based
- Maintenance history, trending, work control and reporting systems
- Overhaul Strategy
- Use of industry experience
- Personnel qualification and training
- Parts procurement
- Self Assessments

All nuclear plants should already have existing processes or mechanisms to support these elements of a circuit breaker maintenance program. Plants may wish to ensure these existing processes adequately support the elements of the plant's circuit breaker program.

For guidelines that describe the key elements of maintenance programs in general, refer to *Guidelines for the Conduct of Maintenance at Nuclear Power Stations*, INPO-92-001, INPO, April 1992.

Background

From 1988 through 1994, EPRI-NMAC funded projects to develop circuit breaker maintenance manuals. These projects resulted in eight published circuit breaker maintenance guides developed by various contractors on low and medium voltage circuit breakers. To further assist in improving circuit breaker reliability and facilitating utility communication, NMAC began forming medium voltage circuit breaker users groups in 1994, starting with the G.E. Magne-Blast users group. Utility response and support of these groups was significant. As the groups matured, it became evident that these groups fulfilled a significant role within the industry and provided a much needed vehicle for communication and technology transfer. Utility support for these groups and meeting attendance remains high.

On November 23, 1996, via a conference call, the NRC staff notified NEI and EPRI-NMAC that a generic letter on medium voltage circuit breakers had been drafted. With EPRI-NMAC assistance, NEI formed a circuit breaker task force to provide the needed higher level oversight, communication, and coordination. After November, 1996, EPRI-NMAC increased its level of support and advanced its timetable of activities.

An NRC Inspection Manual, Temporary Instruction (TI) 2515/137, was issued on December 31, 1997. This TI was used by NRC staff in 1998 to inspect circuit breaker maintenance programs in two plants per region. After NRC TI-2515/137 inspections were performed, the NRC opted not to issue a Generic Letter. Instead, they issued IN-99-013, *Insights from NRC Inspections of Low and Medium Voltage Circuit Breaker Maintenance Programs*, (see Attachment A). Subsequent to the NRC IN, the NRC staff issued a general letter to the industry. The subject of this letter was *Insights from NRC Circuit Breaker Maintenance Program Inspections.*

In September of 1998, the Institute of Nuclear Power Operations (INPO) issued Significant Event Operating Experience Report (SOER) 98-2, *Circuit Breaker Reliability*.

At the time this document was written, the industry's circuit breaker users groups, sponsored by EPRI-NMAC, are continuing to identify and document prudent circuit breaker maintenance practices and provide an industry forum for discussion in this area.

Scope and Applicability

This document is intended for nuclear power plant personnel and is offered for their review and consideration when developing or refining a circuit breaker maintenance program. Although specifically directed to nuclear power plants, the vast majority of the information contained within is also applicable to fossil electric power plants.

Maintenance programs should encompass the circuit breakers within the plant and switchyard that are determined by plant personnel to be important to the safe, reliable, and good economic performance of the plant. This should include the generator output circuit breakers, where applicable.

The scope of this document does not encompass molded case circuit breakers. Molded case circuit breaker programmatic considerations are addressed in EPRI (NMAC) NP-7410-V3, Revision 1.

General Program Considerations

Documentation

A good circuit breaker program should be clearly defined through documentation. This program documentation can be contained within multiple plant documents, policies or procedures, or contained within a single comprehensive document. In any case, the documentation should include, but not limited to

- Program ownership and implementation responsibilities
- Preventive maintenance procedures
- Corrective maintenance or root-cause analysis procedures
- Circuit breaker overhauls
- Facilities, tools and equipment
- Training
- Maintenance task frequencies and work scheduling
- Technical justifications *(Frequencies, calculations, etc)*
- Design basis considerations
- Use of industry experience
- Periodic assessments of the program
- Vendor documentation and interface
- Detection of adverse conditions
- Procurement of parts and services
- Receipt inspections, and pre-installation testing, and post maintenance testing

Although not required, several nuclear plants have chosen to develop a single administrative document that documents their complete circuit breaker program.

Organizational Responsibilities

An effective circuit breaker maintenance program includes a clearly defined program 'owner' along with clearly defined functions and responsibilities for the multiple and diverse groups necessary for program implementation.

Tracking and Traceability – Unique Identifiers

During maintenance and plant operation, circuit breakers may be transferred from one switchgear cubicle to another. To ensure each circuit beaker is properly maintained, maintenance should be tracked by a unique identifier or serial number. Unless plant procedures prohibit interchangablity of circuit breakers from one cubicle to another, maintenance should not be traced (tracked) by cubicle number. Plant personnel should be aware that some circuit breakers have shop order numbers, or other numbers, which are not unique identifiers for individual breakers. If unique identifiers do not exist, a means for unique identification should be established.

Criterion VIII of 10CFR Appendix B (Quality Assurance Criteria) states "Measures shall be established for the identification and control of materials, parts, and components . . . These measures shall assure that identification of the item is maintained by heat number, part number, serial number, or other appropriate means . . ."

Unique identifiers are also useful in organizing historical information gathered for detecting adverse conditions.

Supporting Design Basis

A maintenance program should ensure that circuit breakers are expected to operate reliability during all plant design conditions. Some primary attributes of concern are

1. Proper electrical coordination and protection
2. Adequate operation during fast bus transfers where applicable,
3. Maintaining equipment environmental qualification where applicable.
4. Circuit breaker operation during minimum control voltage conditions,

The plant protection schemes should be designed to ensure reliable operation of the system, including proper and timely operation of the circuit breakers.

Circuit breaker timing tests should be included in the program for the circuit breakers required to fast-transfer per plant design. Some plants have design and regulatory requirements to verify bus transfer times. These times are based primarility on the brekaer operation time and should be verified as a part of maintenance program.

Control Voltage Calculations

Control voltage calculations should be developed to conservatively demonstrate on a continuing basis that the circuit breakers will perform their intended function during their worst-case design basis events. The following should be considered when preparing or reviewing control voltage calculations.

- The minimum calculated control voltage should be the voltage available at the trip and close coils of the circuit breaker.
- Calculations should consider the minimum battery voltage, cable losses, and voltage drops including
  - DC battery voltage (state of discharge) for the duration of design basis events
  - DC battery voltage for the duration of a station blackout event
  - Other expected loads on the batteries during design basis events.
  - Battery design margins
  - Battery aging margins
  - Battery temperature correction factors
  - Control cable length, sizes, loading factors and resistance values
  - Conductor temperature rise
  - Circuit breaker charging motor inrush

Section V, *Control Voltage Calculations*, of the attached NRC supplemental letter (Attachment B) briefly discusses the above considerations.

Use of Spares

Spare circuit breakers provide an added level of flexibility and contingency. A circuit breaker due for preventive maintenance, overhaul, or corrective maintenance can be replaced with a spare. This can be especially important when a breaker failure occurs and timely replacement is critical. Utilization of spare breakers in a maintenance program provides options when scheduling maintenance and supports the on-line maintenance concept. Equipment unavailability times can be also be reduced in support of overall plant goals.

Receipt Inspections

Receipt inspections should be performed whenever circuit breaker maintenance work is performed by any service provider, whether a third-party or the original equipment manufacturer. NRC and INPO correspondence both emphasize effective receipt inspections. To ensure breakers are fully functional before installation.

Although not required, it is considered good practice to perform receipt inspections shortly after receipt of the breaker on-site. This practice helps to facilitate contract issues or other problem resolutions with the supplier.

Another related item to consider is disposition of circuit breakers that may have been stored for an extended period of time prior to use. Some level of condition inspection should be performed to ensure proper circuit breaker function.

Program Self Assessments

Periodic assessment of a circuit breaker maintenance program is an effective tool to ensure that all program elements are adequately addressed. It is also a tool to confirm that written policies and procedures are being adequately implemented. Attachment E provides some example self-assessment tasks, objectives, and criteria that have been successfully implemented in several plant assessments.

Routine Preventive Maintenance

Definition

Routine preventive maintenance requires minimal or no disassembly and is performed to ensure a circuit breaker is in good operating condition and will operate reliably until the next scheduled maintenance. Routine preventive maintenance is also used to monitor the condition of the breaker and correct any minor problems or degradations.

Procedures

Preventive maintenance procedures should be clear and concise where a properly trained technician or team can adequately perform the routine maintenance per program expectations.

PM procedures should consider current vendor recommendations and industry experience. Vendor recommendations include tasks required in instruction books, maintenance manuals, and all applicable technical notices (service advice letters, service information letters, technical bulletins, etc.) Industry experience should include documents from the NRC (Information Notices), Institute of Nuclear Power Operations (INPO) (OE's, SERs, SOERs, etc.), and industry groups such as owners (users) groups. A strong technical justification for any task performed (or not performed) that do not agree with vendor recommendations or industry experience should be well documented.

Preventive maintenance guidance for many of the breakers in service within the nuclear power plants has been developed by ERPI-NMAC. These documents are listed in the reference section of this document.

As-Found Data

The purpose of taking as found data is to document, to the extent possible and practical, the condition of the circuit breaker prior to maintenance. By documenting the condition of the circuit breaker prior to maintenance, a maintenance history is acquired in the plant records. This maintenance history can serve as one input to the overall circuit breaker maintenance program. Collecting and reviewing the as-found data of the aggregate circuit breaker population can be useful in adjusting maintenance intervals, if adjustment is desired in the future.

An additional, more practical benefit of taking as-found data is to determine any degraded conditions early during maintenance to facilitate work scheduling, ordering parts, etc. Examples of as-found tests and inspections include

- Reduced control voltage
- Contact resistance
- Trip shaft torque (AKR)
- Trip shaft force (DS)
- General circuit breaker condition

Specific insulation resistance values should be recorded rather than simply noting satisfactory of unsatisfactory conditions. Recording as-found insulation resistance (Megger®) data provides the ability to compare previous or future data and the ability to better access the effectiveness of maintenance.

Minimizing Preconditioning

The sequence of maintenance tasks within a PM procedure should minimize, to the extent practical, any preconditioning of a circuit breaker. It is understood that preconditioning can not always be completely eliminated, but it can be minimized with the appropriate task sequence.

Trending and Maintenance Rule Reporting

INPO SOER 98-2, Recommendation 4-C, states "Review circuit breaker maintenance history records for trends periodically to identify failures that may indicate degradation or repeated failures of the breaker."

INPO, the NRC, and the industry's circuit breaker users groups all agree that plants are not required to perform trending beyond what is already performed under the Maintenance Rule. All circuit breaker failures are normally captured within maintenance rule reporting programs. In addition, maintenance rule requirements provide for periodic assessments to ensure that all adverse conditions are captured. Plants can either monitor circuit breakers within the systems of the loads they supply or within their own system (AC/DC Distribution System). If circuit breakers are monitored (reported) within the systems of the loads they supply, specific circuit breaker adverse trends may not become apparent.

Trending of parameters on low and medium voltage circuit breakers have not seen widespread use nor have been proven consistently effective by the industry. The following parameters have been suggested as trendable items, however, there is no historical data to support this:

- Timing and Travel analysis – Per EPRI this is not trendable.
- Lubrication analysis – Not practical as the sample sizes are to small.
- Reduced control voltage testing
- Thermography
- Trip Shaft Force (Torque)

Condition and Predictive Based Maintenance

Circuit breaker maintenance has typically been performed as a time (or calendar) based maintenance task. A time-based approach is still the preferred method to schedule maintenance. Historically, circuit breakers do not lend themselves to traditional condition based maintenance technologies such as vibration, ultrasonics, lubrication analysis, or thermography. An exception to this is the use of thermography on molded case circuit breakers.

Circuit breaker condition can be based on visual inspection and testing. Experienced maintenance personnel can often judge the condition of a circuit breaker by touching (feeling) and listening to the operating mechanism during opening and closing operations. Obviously, this is a subjective measure and requires a great deal of experience of the part of the technician.

Reduced Control Voltage Testing

Reduced control voltage testing is typically done before (and can be done after) routine preventive maintenance and can be a part of condition based maintenance. Refer to EPRI's *Reduced Control Voltage Testing of Low and Medium Voltage Circuit Breakers*, EPRI TR-112814.

Timing and Travel Analysis

Timing and travel analysis testing can be a part of condition based maintenance. Refer to EPRI's *Circuit Breaker Timing and Travel Analysis*, EPRI TR-112783.

PM Intervals (Frequencies)

It is the responsibility of each plant to determine its own circuit breaker maintenance intervals. The justification for these intervals should be documented in the plant's maintenance program.

Deviations from manufacturer's maintenance interval recommendations are acceptable, provided these deviations are technically justified and well documented. Manufacturers typically provide guidance on maintenance task intervals. This guidance, by their own admission, represents their best generalized advice, and may include conservative assumptions about the circuit breaker's environment, lubrication, previous maintenance, and operational history. Without exception, manufacturers' encourage plant personnel to identify plant-specific considerations and modify their maintenance intervals as needed. The following two excerpts from manufacturer's manuals reinforce this point.

1. Westinghouse's Instruction Bulletin (I.B.) 32-253-4B states "*Because these breakers are applied in a broad variety of applications under unique combinations of environmental conditions, each having operating duty requirements that can vary widely, it is virtually impossible to outline a specific maintenance schedule which would be universally appropriate for all rating of circuit breakers in all types of applications.*"

2. ABB's Maintenance and Surveillance (MS) 3.2.1-9-1D states *"Suggested time frames in the program are not absolute, they represent the best generalized advice of the manufacturer . . . "*

A variety of factors should be considered when determining circuit breaker maintenance intervals (frequencies). Depending on a plant's particular situation, each factor may have more or less importance. Significant factors affecting maintenance intervals include the following.

I. Industry Experience
   A. Industry experience with maintenance of circuit breakers with similar design, age, lubrication, environment, and maintenance and operational history.
   B. Other significant industry experience which may be applicable or affect the maintenance interval.

II. Current Condition
   A. The current condition of circuit breakers can be evaluated to the extent possible and considered when determining preventive maintenance intervals. This could be performed via sampling and inspecting typical circuit breakers.

III. Lubrication
   A. In-service anticipated life of the lubricant
   B. Actual or typical lubricant condition at your plant
   C. Type of lubricant used.

IV. Maintenance History
   A. Previous maintenance performed
   B. Previous lubrication practices
   C. Previous environmental effects
   D. Previous routine maintenance intervals
   E. Findings and Deficiencies identified during preventive maintenance and 'as-found' data

V. Operational history
   A. Number of operations since last maintenance performed - Degree to which circuit breaker is "exercised" or cycled.
   B. Duty cycle (i.e. rough % carrying load and what % of breaker rating this represents)
   C. Quantity and severity of fault interruptions or overcurrent conditions since last maintenance interval- distinguishing between overloads (time overcurrent) and fault level currents (instantaneous operations)
   D. Number of clearances and associated racking-in/out (wear on main and auxiliary contact/connectors)

VI. Circuit Breaker Significance

A. The importance of the breaker, which includes

1. Its safety significance, (use of PRA and IPE for prioritization of circuit breakers for maintenance)
2. Its commercial or economic significance

VII. Maintenance Philosophy

A. The utility's or plant's current maintenance program and philosophy.

VIII. Environment

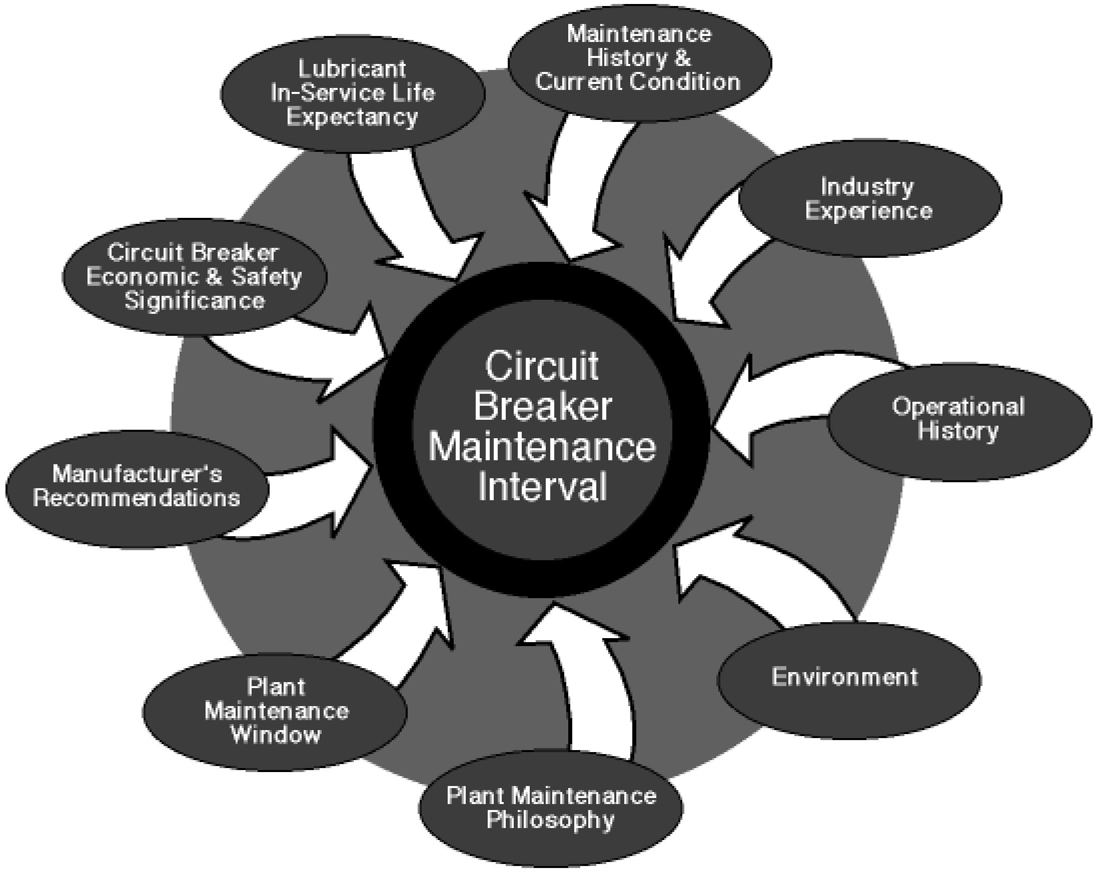
A. Past and current service condition or environment

IX. Maintenance Windows

A. Availability of the Circuit Breaker for maintenance
B. Outage (Refueling) schedule
C. Use of on-line maintenance
D. Critical/Non-Critical Nature of the Breaker (i.e. LCOs and need for power production)

X. Manufacturers recommendations

A. Recommendations provided by the manufacturer through manuals, letters, or bulletins.


Lubricant
In-Service Life
Expectancy
Maintenance
History &
Current Condition
Industry
Experience
Circuit Breaker
Economic & Safety
Significance
Circuit
Breaker
Maintenance
Interval
Operational
History
Manufacturer's
Recommendations
Environment
Plant
Maintenance
Window
Plant Maintenance
Philosophy

Lubrication

Identifying Lubricants

A maintenance program should document the manufactuer's currently recommended lubricant or other approved lubricants for each circuit breaker. Circuit breaker manufacturers normally provide a list of recommended lubricants in the instruction bulletin(s). Care should be taken to ensure the recommendations are up-to-date. If deviating from manufacturer's recommendations, an appropriate justification should be documented.

Where to Lubricate

Maintenance procedures should specify the exact location and, to the extent practical, the amount of each type of lubricant used on a circuit breaker. This can be done either through descriptive text, schematics, or pictures. Maintenance procedures should be specific enough to ensure consistency in the lubrication practices. Lubrication practices should be addressed in detail within the plants circuit breaker maintenance training program.

Shelf-Life – Storage and Handling

Lubricant self-life is addressed in Section 3.2 of the NMAC *Lubrication Guide* (EPRI NP-4916-R2). This section is contained in Attachment C of this document. This section discusses why lubricant suppliers often limit the recommended self-life to approximately 2-3 years. Summarizing the NMAC Lubrication Guide, lubricants are very stable for many years if stored under the proper conditions. Proper conditions consist of controlling lubricant temperature and minimizing contamination. A simple inspection that includes looking, feeling, and smelling the lubricant can verify the lubricant is still acceptable. For more detailed criteria, consult the NMAC Lubrication guide. Based on the NMAC guidance, some plants have given lubricants an indefinite shelf life. Alternatively, plants may utilize the self-life as a means of control to ensure that contaminated or excessively old grease is not utilized. However, lubricant self-life can certainly be extended beyond the suppliers recommended self-life, as long as criteria for its use and storage are reasonable, communicated, and understood.

Lubricant Compatibility and Certification

Lubricant compatibility becomes an issue when old and new lubricants are mixed. If co-mingling of lubricants is necessary, compatibility should be verified. Co-mingling of incompatible greases may be worse than leaving in the old grease. Few, if any, vendor recommendations allow the mixing of lubricants. Some manufacturers allow for "revitalization" of lubricant during routine preventive maintenance to allow a circuit breaker to operate properly until an overhaul can be performed. Ensure the lubricant(s) used has (have) an adequate certification for the breaker quality classification.

Insulation Resistance Acceptance Criteria

The EPRI-NMAC circuit breaker users groups have adopted the guidance provided in the InterNational Electrical Testing Association's *Maintenance Testing Specifications* document (NETA MTS-1997).

This NETA guidance is currently referenced in the various EPRI-NMAC circuit breaker preventive maintenance guidance documents and is contained in Attachment D of this document. See attached list of references.

Maintaining Knowledge and Skill Level

Some plants with successful maintenance programs have formed circuit breaker "teams" or have selected and trained specific individuals to perform circuit breaker maintenance. Due to the complexities and subtleties of breaker maintenance, it is important to ensure that the knowledge and experience level of circuit breaker technicians remains high.

Another characteristic of successful maintenance programs is management support. Management support and awareness is a critical aspect when maintaining the knowledge and skill-level of the plant's circuit breaker technicians.

Corrective Maintenance

Troubleshooting

When circuit breaker failures occur, the performance of routine preventive maintenance procedures should not be used in place of proper troubleshooting techniques. General troubleshooting guidance should be developed and used in training programs to enhance staff expertise. Also, specific troubleshooting plans, where appropriate, can be developed to ensure accurate root cause determinations for circuit breaker problems.

Quarantine Procedures

If a circuit breaker fails to operate it is important to preserve the condition of the circuit in the failed position so troubleshooting can proceed from that point in a systematic manner. Quarantine procedures should maintain the circuit breaker in the "failed as-is" state to the extent permissible by plant conditions. It is important that operations personnel are aware of the importance of quarantining and how it can enhance the path to a successful root cause determination.

Root Cause Investigations

Accurate and effective root cause investigations evolve from good troubleshooting techniques and the ability to quarantine circuit breakers with failures. Root cause investigations should be well documented and lead to improvements in the circuit breaker maintenance programs where appropriate.

Re-installing breakers when cause of failure is not known is not recommended. Root cause investigations should include reviews of previous maintenance histories of the failed circuit breaker. This helps ensure that circuit breaker adverse trends are detected as soon as possible.

Troubleshooting techniques and procedures, where applicable, can include use of boroscopy, high-speed video systems, lubricant tribology, and time-travel analysis.

Overhaul (Refurbishment)

Definition of Overhaul

Overhaul of a circuit breaker is defined as complete disassembly (no two piece parts assembled) of a circuit breaker to the extent practical for the purpose of restoring the circuit breaker to a like-new condition. An overhaul can also be obtained through replacement of the operating mechanism and overhaul of the remaining circuit breaker sub-assemblies. For the purposes of this document, the terms 'overhaul' and 'refurbishment' are used interchangeably and have the same meaning.

Establishing a Program

A circuit breaker maintenance program should address if, and when, an overhaul is required for each circuit breaker within the program. Regardless of whether a time-based or condition-based overhaul philosophy is chosen, the reasons and justification should be well documented.

As with preventive maintenance intervals, an overhaul interval (frequency) should be justified and documented as discussed in the *Preventive Maintenance Intervals* section of this document.

Design Life

Circuit breakers are certified and tested per industry standards. They are tested to a specific design life that is measured in number of cycles. This number of cycles is different for different model circuit breakers. Overhaul of a circuit breaker will not restore all circuit breaker components to a new condition and therefore the (design-life) cycle counter should not be re-set.

Overhaul Lubrication

During overhaul, old lubricants must be completely removed using an approved solvent. If using a lubricant not recommended by the manufacturer, the effect (compatibility with breaker materials, lubrication properties,) on breaker parts should be considered and, if necessary, evaluated.

Overhaul Program Considerations

When overhauling circuit breakers, plants either perform their own overhauls, or hire another organization to perform the work. This other organization may either be the manufacturer or a third-party service provider. In each case, plant personnel have unique considerations and challenges, depending upon the type maintenance program chosen.

Performing Overhauls "In House"

"In house" overhaul programs provide utility personnel with the maximum degree of ownership of the program. This approach requires a large commitment from plant management and staff. The following items should be considered when taking this approach.

<u>Consistent Management Support for the Overhaul Program</u>
Consistent, long term management support is necessary if a utility is to have an effective "in house" overhaul program.

<u>Maintaining Knowledge and Skill Level</u>
Some plants with successful "in-house" overhaul programs have formed circuit breaker "teams", or have selected and trained specific individuals to perform circuit breaker overhauls. These individuals can be qualified through special training that often includes the manufacturer or a 'third party' with considerable overhaul experience for the subject breaker.

Due to the complexities and subtleties of breaker maintenance, it is important to ensure that the knowledge and experience level of circuit breaker technicians remains high. To maintain skill levels, overhauls can be performed, to the extent possible, on a rotating basis or as on-line maintenance.

Another characteristic of successful overhaul programs is management support. Management support and awareness is a critical aspect when maintaining the knowledge and skill level of the plant's circuit breaker technicians.

<u>Facilities and Tools</u>
Special facilities and tools may be required for an in-house overhaul program. These resources and costs should be considered and planned for.

<u>Parts</u>
Utility personnel have noted difficulties in obtaining parts for their own overhaul programs. When parts are available, the cost of parts has been an issue. Parts availability from the manufacturer should be verified. Parts availability and parts costs should be considered. Some manufacturers may be reluctant to provide parts as they may perceive utilities as competitors.

<u>Manufacturer Assistance and/or Oversight</u>
Manufacturers or service providers may send a representative to oversee and provide technical assistance for circuit breaker overhauls. This may or may not be necessary, depending upon the

level of in-house expertise and plant's breaker maintenance program. Some manufacturers (vendors) may be reluctant to provide this service as they may perceive utilities as competitors.

<u>Training</u>
More detailed training is needed if overhauls are performed by utility personnel. This training can be obtained through the manufacturer (if they are willing), through other vendors, or other utilities which perform their own overhauls. Experience is a major factor in being able to successfully implement an in-house overhaul program.

<u>Parts Modifications or Enhancements</u>
Circuit breaker parts modifications, upgrades, or enhancements should be identified. This information can come from the manufacturer or the manufacturer's authorized service provider, manufacturer's literature, industry documentation, and other utilities that perform similar work.

Overhauls by the Manufacturer or Service Provider

Overhauls are provided by all of the original equipment manufacturers or their authorized service providers. Overhauls are also performed by third parties or organizations other than the manufacturer. Considerations when using this approach include the costs associated with contracting this service and the potential loss of "ownership" of the program by plant personnel. Advantages of this approach

<u>"Know What Your Getting"</u>
Plants should "know what they are getting" when their breakers are overhauled. Plants may review a vendor's procedure or specification, and/or provide their own specifications. Also, it is typically beneficial to send a representative to the vendor's overhaul facility to access the process, facility, and work being performed. If cost effective, a plant may consider having the overhauls performed at your site. Also, plants may consider including quality assurance (QA) "Hold Points" or "Witness Points" for circuit breaker work performed by a service provider.

Overhaul specifications

Even though you may be dealing with the original manufacturer, it is beneficial to the utility to still specify, via the purchase order or contract, exactly what is expected, as expectations may not be met. If possible, review the service provider's specifications and/or overhaul procedure. After reviewing the service provider's procedures and specifications, provide your own specifications, and procedures, and requirements regarding parts, modifications, testing, etc. (See below)

Parts

Ask the service provider to identify parts which are normally replaced and included in the overhaul contract price. Ask the service provider to identify other parts replaced and list reason for the replacement. Documentation for the parts replaced should also be provided.

Parts Modifications and Enhancements

Ask the service provider to specify and document any and all parts modifications or enhancements. If utilizing a third party rather than the original manufacturer, the third party may not be aware of any parts modifications or enhancements. Care should be taken that any modifications or enhancements are made which are required by the plant.

As Found Testing

Specify this testing as part of the contract or perform this testing upon removing the circuit breaker from the cubicle.

As-Left-Testing (Pre-shipment)

Specific as-left testing should be specified as part the purchase order or contract.

Receipt Inspections (Post shipment)

Receipt inspections and tests are expected to identify any problems with the circuit breaker after shipment and/or prior to the return of service. Some plants perform the entire routine maintenance procedure as a receipt inspection.

Pre-Installation Checks

Pre-installation checks include checking the interface between the breaker and switchgear as outlined in the maintenance guidance documents.

Post Maintenance Testing

Typically the post maintenance testing will place the circuit breaker in service and voltage and load current will be verified on all three phases. Plant conditions may be such that loading the circuit breaker when it is returned to the electrical board will result in unnecessary perturbations to the system.(i.e. Alternate feeder breaker return to service.) In these cases some administrative mechanism should be used to track the PMT until such time the circuit breaker can have load current and line voltage applied.

Utility Centralized Shops

Preventive maintenance and/or overhauls are sometimes performed by a corporate or centralized team. This team should be familiar with all of the above considerations and the individual requirements of the plant.

Reduced Control Voltage Testing

Reduced control voltage testing is recommended to be done after (and can be done before) an overhaul. Refer to EPRI's *Reduced Control Voltage Testing of Low and Medium Voltage Circuit Breakers*, EPRI TR-112814.

Timing and Travel Analysis

Timing and travel analysis testing can be be done after (and can be done before) an overhaul. Refer to EPRI's *Circuit Breaker Timing and Travel Analysis*, EPRI TR-112783.

Industry Experience

Industry experience reports come from various sources and in various forms. Industry experience includes

- NRC Information Notices (INs) and letters
- NRC Part 21 reports
- Manufacturer's Letters (GE Service Advice Letters (SALs), Westinghouse Technical Bulletins, Infograms, Instruction manuals, maintenance manuals, GE Service Information Letters (SILs), Product Bulletins, Eaton Cutler-Hammer Product Information Notices, Part 21 Reports)
- INPO documents (SOERs, SENs, OEs, O&MRs, MERs.)
- Industry meetings and conferences
- EPRI guidance documents

Plants should have an effective process to review all the various forms of industry experience reports and incorporate the information learned from these reports as applicable. Some plants have placed industry experience reports relating to a single type of circuit breaker into a single location or document.

Industry users groups are good information sources to ensure that all such reports on circuit breakers are communicated to utility personnel. Industry groups may also be a good source of industry experience and related information.

Generic Applicability

Problems or issues identified with one specific type circuit breaker may be applicable to another type circuit breaker (of different model or manufacturer) due to the similarities in circuit breaker construction and function. Plant personnel familiar with circuit breakers should be responsible for evaluating and determining the applicability of circuit breaker industry experience reports. Attachment B, *NRC Insights from NRC Circuit Breaker Maintenance Inspections*, Section VI, *Operating Experience Review*, contains six examples of NRC Information Notices which have some degree of generic applicability. These Information Notices are

- IN 83-50; Failures of Class 1-E, Safety Related Switchgear Circuit Breakers, Aug 1, 1983
- IN 84-46; Circuit Breaker Position Verification, June 13, 1984
- IN 90-41; Potential Failure of GE Magne-Blast Circuit Breakers and AK Circuit Breakers, June 12, 1990
- IN 93-85; Problems with X relays with DB and DHP Circuit Breakers Manufactuered by Westinghouse, October 20, 1993
- IN 97-53; Circuit Breakers Left Racked Out in Non-Seismically Qualified Positions, July 18, 1997

Vendor Interface (Generic Letter 90-03)

With regard to circuit breakers, NRC inspection reports and plant self-assessments have identified several issues with implementation of Generic Letter 90-03.

1. Some plants were not periodically contacting circuit breaker manufacturers for updates on product technical information.
2. Some plants were attempting contact the manufacturer, but were not contacting the proper representative(s).
3. Some plants were attempting contact the manufacturer, but the person making contact was not technically knowledgeable or responsible for circuit breaker maintenance.

Utility personnel and NRC staff have both noted that incorporating the manfuacturer's service letters (SALs, Tech bulletins, Product Information Notices, etc) into the vendor manuals has proven to be a good practice.

Implementation of GL 90-03 with respect to circuit breakers is complicated due to changes within the manufacturers' names, organizations, and business locations. Maintaining contact with the manufacturer and industry groups is important to ensure adequate implementation of this program.

Personnel Qualification & Training

The Institute of Nuclear Power Operations (INPO) has published the Guidelines for Training and Qualification of Maintenance Personnel, ACAD 92-008, which provide the framework for maintenance personnel training and qualification programs at nuclear power plants. These guidelines incorporate the results of an industry-wide job and task analysis. The guidelines are intended to be used in combination with plant-specific job and task analysis to develop and revise training programs.

Utilities should use these guidelines in conjunction with plant-specific job and task analysis results when establishing upgrading or validating maintenance training programs.

Breaker crews often consist of an experienced journeyman and an apprentice. In order to develop a training program and qualify crews, the total scope of work to be performed onsite should be defined. For the purposes of this maintenance guide, the scope of work will consist of three major areas: 1) preventative maintenance 2) corrective maintenance, and 3) breaker overhaul.

Preventative and corrective maintenance will normally be performed by an experienced journeyman, and possibly an apprentice. The maintenance apprentice should be trained on the equipment to the extent that common failure mechanisms and operating principles of the circuit breaker are readily known. For both preventative and corrective maintenance, the journeyman should have specialized skills training. As a minimum, the journeyman should be able to demonstrate disassembly and assembly methods, adjustment and calibration steps, and repair and part replacement techniques. The journeyman should also be proficient with all measuring and test equipment. As mentioned earlier in the section on lubrication, it is important that maintenance personnel are trained on proper lubrication methods.

Breaker overhaul is typically performed by individuals who are considered job specialists. Overhaul is not directly addressed by the INPO training document. During the utility phone survey, the overhaul process was discussed with site personnel. Most utilities that accomplish the process on-site utilize a vendor representative, journeyman, and an apprentice. The vendor representative conducts on-the-job training and provides technical guidance as needed. Most individuals felt confident after performing three to four breaker overhauls.

If a utility chooses to establish a formal training program targeted to overhauls, it is recommended that the proposed instructor work with the OEM instructor until proficiency is established.

Training Considerations

If deemed appropriate, circuit breaker crews should be trained on significant modifications that have been implemented within the plant's breakers. In the same way, significant procedure changes or revisions may warrant continuing training of circuit breaker maintenance personnel. Technicians should be trained on lubrication points, lubricant types, etc.

Operator Training

Operations training should stress the importance of quarantining failed circuit breakers when plant conditions allow.

Operators could also be provided general guidance on how to cope with failures and record key indicators such as indicator lights, breaker charging motor operation, and open and close indicators, as appropriate.

Operator training should encompass proper racking techniques to ensure proper breaker positioning and breaker to switchgear cubicle interface connections.

INPO Guidance on Circuit Breaker Training

The Institute of Nuclear Power Operations (INPO) has developed *Training Materials to Supplement SOER 98-2, Circuit Breaker Reliability*. This document outlines basic learning objectives and learning activities for plant circuit breaker training. Plants should review this to ensure the completeness of their training program.

Parts Procurement

OEM Supplier Considerations

The manufacturer may only be willing to sell specific piece parts, or may only sell assemblies. Before initiating extensive preventive maintenance or overhaul program, parts availability and lead-times should be assessed.

Part obsolescence is also a consideration. Although a manufacturer or service provider may still service or support a product line, larger or specialized components such as arc chutes or pole pieces may no longer be in production.

In addition, changes in sub-component pieces should be adequately evaluated and technical equivalency justifications documented prior to installation in the circuit breaker.

Dedication of Commercial Grade Parts

One method of maintaining a supply of circuit breaker subcomponents and parts, especially consumable items (washers, cotter pins, nuts and bolts, etc), is to procure commercial grade parts and dedicate for safety-related use. This should only be performed when the part's critical characteristics are known, adequately evaluated and documented to ensure their use will not compromise the qualification of the circuit breaker. Although this can be done by a utility, some plants have had success with third party suppliers.

References

- Inspection of Medium-Voltage and Low-Voltage Power Circuit Breakers; NRC Inspection Manual; Temporary Instruction 2515/137, Revision 1
- NRC Temporary Inspection reports for Hatch, 50-321/98-08 & 50-366/98-08; Sequoyah, 50-327/98-05 & 50-328/98-05; Perry, 50-440/98011; Point Beach, 50-266/98013 & 50-301/98013; Callaway, 50-483/98-15; Seabrook, 50-443/98-07; Waterford, 50-382/98-13; Nine Mile Point, 50-410/98-18.
- NRC Information Notice 99-013, *Insights from NRC Inspections of Low- and Medium-Voltage Circuit Breaker Maintenance Programs, April 29, 1999*
- NRC Letter to the Industry, Insights from NRC Circuit Breaker Maintenance Program Inspections, *<Date is missing – On cover letter and orginal>*
- Reduced Control Voltage Testing of Low and Medium Voltage Circuit Breakers, EPRI TR-112814, July, 1999
- Circuit Breaker Timing and Travel Analysis, EPRI TR-112783, May 1999
- EPRI-NMAC Circuit Breaker Maintenance Guide Series, NP-7410; (Three volumes with various parts)
- EPRI NP-4916-R2, NMAC Lubrication Guide, Revision 2. February, 1995
- EPRI-NMAC Circuit Breaker Users Group Meeting Minutes, NRC Presentation on Temporary Inspection inspections. Various dates.
- InterNational Electrical Testing Association's *Maintenance Testing Specifications*, (NETA MTS-1997), 1997
- Significant Operating Experience Report 98-2, Circuit Breaker Reliability, Institute of Nuclear Power Operations, September 18, 1998.
- *Guidelines for the Conduct of Maintenance at Nuclear Power Stations*, The Institute of Nuclear Power Operations (INPO), INPO-92-001, April 1992.
- The Institute of Nuclear Power Operations (INPO) Training Materials to Supplement SOER 98-2, Circuit Breaker Reliability.

- Various nuclear plant self-assessment reports including Sequoyah, Browns Ferry, Watts Bar, Vogtle, and Seabrook.

Attachment A – NRC Information Notice 99-013

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

April 29, 1999

NRC INFORMATION NOTICE 99-13: INSIGHTS FROM NRC INSPECTIONS OF LOW- AND MEDIUM-VOLTAGE CIRCUIT BREAKER MAINTENANCE PROGRAMS

Addressees

All holders of operating licenses for nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to summarize observations made and insights gained during inspections of licensee circuit breaker maintenance programs. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

Because of concerns about the reliability of safety-related medium-voltage (4-kV to 15-kV) and low-voltage (600-V and below) power circuit breakers, the NRC inspected the circuit breaker maintenance programs at eight nuclear power plant sites in 1998, using Temporary Instruction (TI) 2515/137, Revision 1, "Inspection of Medium-Voltage and Low-Voltage Power Circuit Breakers," issued on March 9, 1998. For more detailed information, the individual inspection reports are available through the NRC Public Document Room. Attachment 1 lists the inspection reports and their accession numbers.

The TI inspections confirmed that the programs were generally adequate. However, observations made at several of the plants inspected indicate that licensee programs have several areas in common in which improvement may be desirable. In addition, in a few instances certain aspects of programs did not meet NRC requirements, and violations were cited. Licensees for the inspected plants have already taken steps to address many of the areas of concern identified by the inspections. This notice was developed so that all licensees may take advantage of insights gained from the inspections when considering circuit breaker maintenance program improvements.

Discussion

Significant observations from the TI inspections are described below and have been categorized as follow: (1) general programmatic issues, (2) preventive maintenance,

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(3) licensee/vendor interface, (4) control voltage calculations, and (5) operating experience review. However, licensees are encouraged to review the inspection reports for detailed findings and their resolutions.

I. General Programmatic Issues

Licensee preventive maintenance procedures and practices did not always reflect all of the applicable vendor recommendations or industry operating experience, and when licensees deviated from such recommendations and operating experience there was often no documented basis or rationale given. Adherence to vendor recommendations is not a regulatory requirement, but a sound engineering basis for such deviations is important, and should be performed in consultation with the vendor when possible, to ensure that valuable vendor information is not overlooked.

Storage, shelf life, environment, segregation, and issuance of lubricants and cleaning materials were not well controlled. Some licensees had not identified shelf lives for circuit breaker lubricants and cleaning agents or solvents.

Individual breakers at some plants either did not come with or were not given unique identifiers. Some licensees were not aware that group or series identifiers, such as shop order numbers, were not unique. Some licensees did not record both the breaker serial number, when present, or the cubicle number in maintenance records to allow for tracking of breaker location, performance, and maintenance history.

At most plants, the racking of breakers in and out of the cubicle (and local operation when required) was the job of operations department personnel rather than circuit breaker maintenance personnel. However, operations department training and/or procedures did not always cover breaker position verification or functional testing in the connected position (closing the breaker and running load equipment, when permitted by plant conditions). Training operations department personnel to verify proper indications, closing spring recharging, and restoration of all electrical and mechanical interfaces and interlocks, and cycling the breaker after it is racked in, could result in fewer failures to close on demand.

II. Preventive Maintenance

Preventive maintenance was not always performed with the frequency recommended by the original equipment manufacturer (OEM), and licensees had no documented justification for deviating from that frequency.

Maintenance procedures sometimes did not cover inspection for specific problems identified in industry operating experience. Some licensees stated that they covered such items in training, but specific items in question were seldom explicitly addressed in lesson plans.

III. Licensee/Vendor Interface

The TI inspections revealed that circuit breaker and switchgear vendor manuals were often not kept current, and the programs for periodic recontact provided for in Generic Letter (GL) 90-03 were ineffective in obtaining revisions or updates to vendor manuals, or other pertinent technical information.

Some licensees identified areas in which improvements could be made to vendor interface programs, including (1) periodic review of plant equipment to ensure that lists of key safety-related equipment are current, (2) establishing organizational and procedural interfaces and links to ensure that vendor interface personnel are kept informed of equipment changes or modifications, (3) establishing personal contact with the appropriate vendor personnel, (4) substantial involvement in the process by technically knowledgeable personnel, and (5) periodic comprehensive reconciliation with the vendor of lists of equipment and related technical publications or documentation.

IV. Control Voltage Calculations

The TI inspections revealed that a few licensees had not performed the circuit breaker control voltage calculations based on as-built systems. In some cases where calculations were performed several discrepancies were identified, including (1) not starting with the minimum battery voltage; (2) using an incorrect minimum battery voltage that did not take into account loading, state of discharge, and/or aging factors; (3) using incorrect current paths, cable lengths, conductor sizes, and/or ohms/foot values to determine overall cable resistance; (4) calculation of cable conductor resistance using ambient temperature values, but neglecting temperature rise caused by heat from surrounding cables in a raceway or without having data to justify the non-conservative lower temperature assumption; and (5) using incorrect loading values in the final determinations of voltage drops. One licensee, had not translated this design basis information into test procedures to demonstrate breaker operability (NRC Inspection Report 50-266/98-13).

V. Operating Experience Review

At most of the plants inspected, weaknesses were observed in the review of operational experience documents related to low- and medium-voltage circuit breakers. These documents included NRC information notices (INs); INPO SEE-IN documents or Nuclear Network reports; and vendor information, such as service information letters, technical bulletins, or service advisory letters.

The TI inspections revealed instances of industry operating experience information erroneously determined to be not applicable because of narrowly focused and/or superficial reviews, and insufficient involvement by technically knowledgeable personnel. Problems generically applicable to several types of breakers were often not recognized because the plant's breakers did not have exactly the same model designation as the one used as an example in the information notice or the vendor technical bulletin.

TI 2515/137, Revision 1, lists 62 NRC information notices and bulletins that deal with problems with low- and medium-voltage power circuit breakers. As many as one-third of these were erroneously determined to be not applicable at one or more plants.

Related Generic Communications

IN 98-38, “Metal-Clad Circuit Breaker Maintenance Issues Identified by NRC Inspections,” issued on October 15, 1998, alerted licensees to issues identified by reactive NRC inspections at plants that experienced problems concerning circuit breaker reliability in 1997. The events discussed in that information notice were the catalyst that prompted the TI inspections of licensee maintenance programs in 1998.

Conclusion

This information notice requires no specific action or written response. However, recipients are reminded that they are required to consider industry-wide operating experience (including NRC information notices) where practical when setting goals and performing periodic evaluations under Section 50.65, "Requirement for monitoring the effectiveness of maintenance at nuclear power plants," of Part 50 of Title 10 of the Code of Federal Regulations. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

/s/’d by
Ledyard B. Marsh, Chief
Events Assessment, Generic Communications,
and Non-Power Reactors Branch
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Attachments:
1. Table of NRC TI Inspection Reports
2. List of Recently Issued NRC Information Notices

Attachment 1
IN 99-13
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TABLE 1 - Temporary Instruction 2515/137 Inspection Reports

PLANT	**REPORT NUMBER**	**ISSUE DATE**	**ACCESSION NUMBER**
Callaway	50-483/98-15	10/26/98	9810290263
Hatch 1 & 2	50-326/98-08	04/30/98	9805110181
Nine Mile Point 2	50-410/98-18	11/13/98	9811240071
Perry	50-440/98-11	07/16/98	9807220299
Point Beach 1 & 2	50-266/98-13	09/11/98	9809180178
Seabrook	50-443/98-07	09/28/98	9810050116
Sequoyah 1 & 2	50-327/98-05	06/12/98	9807070138
Waterford 3	50-382/98-13	11/17/98	9811240126

Attachment B – Insights from NRC Circuit Breaker Maintenance Program Inspections

Electric Power Research Institute
ATTN: Mr. Jack Lance
1300 Harris Boulevard
Charlotte, NC 28262

SUBJECT: INSIGHTS FROM NRC CIRCUIT BREAKER MAINTENANCE PROGRAM INSPECTIONS

Dear Mr. Lance:

Because of concerns over the reliability of safety-related low- and medium-voltage power circuit breakers, the U.S. Nuclear Regulatory Commission (NRC) developed an action plan to determine whether regulatory action was needed to ensure that the breakers remained reliable components. As part of the action plan the NRC performed inspections of eight licensee circuit breaker maintenance programs using a special inspection module (Temporary Instruction 2515/137, Revision 1). In addition to those inspections, the staff also performed inspections of original equipment manufacturers and third party vendors that perform breaker refurbishments.

The purpose of this letter is to transmit the insights gained from NRC inspections at nuclear power plants and circuit breaker vendor facilities over the two-year period from 1997 to 1998. The inspection results indicate that the eight inspected licensee maintenance programs for medium-voltage (4 kV to 15-kV) and low-voltage (600-V and below) circuit breakers that supply power to safety-related equipment, are generally adequate and the circuit breakers are still reliable components. However, there are some areas of these maintenance programs that could be improved to ensure that circuit breakers continue to be reliable throughout their service lives. Information Notice (IN) 99-13, "Insights from NRC Inspections of Low- and Medium-Voltage Circuit Breaker Maintenance Programs," was issued on April 29, 1999, to summarize the inspection results for all licensees.

The enclosure to this letter provides a detailed discussion of the topics covered in IN 99-13 so that licensee personnel responsible for developing and implementing circuit breaker maintenance programs may take advantage of the information gathered from the inspection of licensee and vendor facilities. In addition to discussing the topics in IN 99-13 in greater detail, the enclosure also discusses corrective maintenance, refurbishment, and the maintenance rule. The enclosed insights are for information only, so that licensees may consider them when making improvements to their circuit breaker maintenance programs, and are not meant to be construed as new regulatory requirements.

The historical background of the circuit breaker reliability issues that led to the NRC performing the maintenance program inspections is enclosed. Following the background, the insights gained from the NRC inspections are described. The insights have been divided into the following categories: (1) general programmatic issues, (2) preventive maintenance, (3) corrective maintenance, (4) licensee/vendor interface, (5) control voltage calculations, (6) operating experience review, (7) refurbishment, and (8) maintenance rule.

If you have any questions concerning any of the material in the attachment to this letter please contact one of the cognizant staff members listed at the end of the attachment.

Ledyard B. Marsh, Chief
Events Assessment, Generic Communications
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Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Theodore R. Quay, Chief
Quality Assurance, Vendor Inspection,
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Division of Inspection Program
Management
Office of Nuclear Reactor Regulation

Enclosure: Low- and Medium-Voltage Circuit
Breaker Reliability Concerns

cc: J. Sharkey, EPRI
W. Subalusky, INPO
G. Fader, INPO
R. Burris, INPO
D. Modeen, NEI
J. Butler, NEI

Background: Low- and Medium-Voltage Circuit Breaker Reliability Concerns

The NRC issued Information Notice 98-38, "Metal-Clad Circuit Breaker Maintenance Issues Identified by NRC Inspections," on October 15, 1998, to alert licensees to issues identified by reactive NRC inspections at plants that experienced circuit breaker reliability issues in 1997. The nuclear power plants discussed in IN 98-38 either considered shutting down, extended an outage, or actually shut down because of concerns over common-mode failure of their safety-related circuit breakers. In response to those events, the NRC implemented a task action plan to evaluate whether any generic regulatory action was warranted to address power circuit breaker reliability problems. As part of the plan, inspections were performed at eight plants to determine the overall status of the industry's circuit breaker maintenance programs, using Temporary Instruction (TI) 2515/137, Revision 1, "Inspection of Medium-Voltage and Low-Voltage Power Circuit Breakers," issued on March 9, 1998. In addition to the TI inspections, several inspections of original equipment manufacturers and third party vendors were performed as part of the action plan.

Another part of the NRC task action plan was the monitoring of industry initiatives to address circuit breaker reliability issues. NRC representatives have attended portions of the Electric Power Research Institute's Nuclear Maintenance Applications Center (EPRI/NMAC) Circuit Breaker Users Groups over the last two years. The users groups, formed to develop maintenance and refurbishment guidelines for medium- and low-voltage power circuit breakers manufactured by General Electric, Westinghouse, and ITE/ABB, have been aggressively pursuing resolution of the breaker reliability issues and are developing guidance based on industry experience and vendor recommendations. The vendors, although reticent at first, have become increasingly involved over the last year. The EPRI/NMAC groups have already issued guidance for the General Electric Magne-Blast (4-kV) breakers, and plan to have the maintenance guidance for all of the 4-kV and 480-V breakers made by the three manufacturers issued by the end of 1999 or early 2000. Although the staff has not reviewed any of the final guidance documents, NRC representatives have seen some of the draft documents at the various users group meetings and they appear to be of high quality.

NRC staff also met with the Nuclear Energy Institute's (NEI) Circuit Breaker Task Force in December 1998. The NEI task force is made up of representatives from NEI, EPRI/NMAC, leaders of the EPRI/NMAC users groups, and the Institute of Nuclear Power Operations (INPO). The staff discussed with the task force a way to share the insights gained from the TI inspections that were performed in 1998. The staff and the NEI task force believe that it is important to share the inspectors' insights, as well as the inspection results, with the industry, especially since the EPRI/NMAC circuit breaker maintenance guidelines are being drafted and many licensees will be revisiting their maintenance programs to see where improvements can be made once the guidelines are issued.

Circuit Breaker Maintenance Inspection Insights

I. General Programmatic Issues

Licensee preventive maintenance procedures and practices could be improved by ensuring that all of the applicable vendor recommendations or industry operating experience are taken into consideration. Inspection results indicate that when licensees deviated from such recommendations and operating experience there was often no documented basis or rationale given. Although vendor recommendations may not be appropriate in some cases, it is important to have a sound engineering basis when deviating from those recommendations. Discussion with the vendor about the reasons behind their recommendations can help to ensure that a licensee has not overlooked something important when deciding to deviate from a vendor-recommended practice.

Control of the storage of lubricants and cleaning materials (including appropriate resealable containers or dispensers, shelf life, environment, segregation, etc.) is important. Some licensees had not identified shelf lives for lubricants and cleaning agents or solvents used in the maintenance of circuit breakers. Procurement and commercial-grade dedication documents did not always identify shelf lives where there were shelf lives associated with the materials. One licensee had identified a resealable container as a critical characteristic for dedication of a lubricant, but receiving documents did not reflect verification of that critical characteristic. Guidance for useful lives of these materials when in use after original containers had been opened (sometimes referred to as "pot life") was not often established. Guidance for storage and handling of these materials after issue to maintenance personnel was typically not provided (e.g., requirements for storage environments, avoiding prolonged exposure to air or high temperatures, avoiding moisture or other contaminants, etc.). Supply issue procedures did not always require that lubricants be issued only on work orders for equipment for which the material was approved and in limited quantities. Maintenance procedures often were not specific about where certain lubricants or solvents should or should not be used on breakers.

A good training program for maintenance personnel should include: (1) specific qualification for various maintenance tasks on different types of breakers, (2) review of industry operating experience, (3) vendor-recommended modifications or upgrades, (4) vendor manual revisions, or (5) plant procedure revisions. At some plants, maintenance procedures did not cover inspecting breakers for specific problems identified in industry operating experience. Some licensees stated that they covered such items in training, but the inspectors found that specific items in question were seldom explicitly addressed in lesson plans. Also, maintenance personnel were not always familiar with some of the test equipment. At one plant, the electrical maintenance supervisor instructed electricians to perform runup reduced control voltage tests using a variable power supply and chart recorder, but the electricians were not familiar with the test equipment. After they experienced some difficulty with the equipment, instrumentation and control technicians were summoned to assist.

Unique identifiers on individual breakers are important for tracking breaker performance and maintenance history. Individual breakers at some plants do not have unique identifiers, and some of the licensees inspected did not know that group or series identifiers, such as shop order numbers, are not unique. Some licensees did not record both the breaker serial number, when present, or the cubicle number in maintenance records to allow for tracking of breaker location, performance, and maintenance history.

At most plants, the racking of breakers in and out of the cubicle (and local operation when required) is the job of Operations Department personnel. Operations personnel training and/or procedures could be improved by covering (1) verification and adjustment, if required, of cubicle interfaces in the connected position (or calling for Maintenance Department personnel to do this) and (2) functional testing in the connected position (i.e., starting, running, and stopping the load equipment when permitted by plant conditions) to verify post rack-in breaker operability in the fully connected position. This practice provides for verification of proper indications, closing spring recharging, and restoration of all electrical and mechanical interfaces and interlocks. These functions were sometimes covered to some extent by post-maintenance testing procedures. However, they were often not prescribed if for some reason a breaker was racked out (even if only to the test position), but no maintenance was performed on either the disconnected or racked-out breaker itself or its load equipment.

Having spare breakers on hand (particularly ones that have been refurbished and are certified for safety-related service) can allow flexibility for interchanging breakers in support of refurbishment, preventive maintenance, or in some cases, to replace a failed breaker in a timely manner, if necessary. Maintenance workers sometimes are under pressure to perform preventive maintenance within a short time in order to minimize the time that equipment served by a breaker (or the breaker itself) is out of service. Licensees have reported that much of this pressure is due to a provision of 10 CFR 50.65(a)(3) which recommends assessing and managing the risk associated with taking equipment out of service for planned maintenance. Having a ready spare to replace a problem breaker could alleviate some of the time pressures.

II. <u>Preventive Maintenance</u>

Some licensees did not always adhere to their own preventive maintenance schedules. At several plants breakers were found to be currently overdue for preventive maintenance with respect to licensee-established periodicity (as well as that recommended by the vendor), or were overdue on one or more occasions in the past.

Recording as-found breaker conditions and comparing them to previous as-found and as-left conditions can help maintenance personnel assess the amount of degradation since the last maintenance, or the effectiveness of the latest maintenance. As-found values of preventive maintenance parameters that could provide useful information include, the trip and close voltage, tripping current and times, insulation resistance, and contact resistance. These parameters should be measured and documented before making adjustments, cleaning, or operations that would tend to alter the as-found conditions. Consistently performing maintenance steps in a prescribed sequence designed to minimize preconditioning (because it cannot be completely eliminated) should provide more valid, comparable or trendable results.

Some vendor manuals prescribe functional testing of circuit breakers (i.e., closing and tripping electrically) at the minimum (and maximum) vendor-specified voltage for the closing solenoid, closing spring release solenoid, or tripping solenoid (e.g, Westinghouse MPM-DS). Others simply provide the voltage range within which the solenoids are designed to operate without explicitly prescribing testing at those extremes of solenoid design capability. However, reduced (i.e., less than nominal) control voltage testing as one means of (1) verifying current operability at the minimum expected (design-basis) or calculated control voltage available at the breaker, (2) confirming past operability, (3) determining margins to unsatisfactory performance, or (4) obtaining diagnostic, predictive, or trendable performance data, has not been routinely performed at all plants in the past. Some licensees have recently begun to obtain quantitative, trendable data on the minimum “pickup” voltages for the control devices which also reflects the condition of breaker tripping and closing mechanisms; or at least to determine if such data are trendable and useful in diagnostic condition assessment or performance prediction.

Although reduced control voltage testing is not a regulatory requirement, testing the most important breakers at reduced voltage may provide added assurance that these breakers would remain operable under worst-case conditions. Breakers such as the EDG output breaker, offsite power source breakers, or other breakers (including some loads that are sequenced on early or that remain connected to vital busses) may be required to close with minimum design control voltage under conditions such as initial recovery from a prolonged station blackout before battery chargers become available. However, certain others (e.g., later sequenced ECCS equipment breakers) that could see minimum design control voltage under some conditions may never be required to operate to perform any of their safety functions at less than nominal voltage because, for example, they are not required to close until after the standby emergency ac power source (e.g., a diesel generator) has restored power to the battery chargers, and hence vital 125-Vdc bus voltage, which is most often used for safety-related breaker control power, is restored to nominal (unless for a given plant, the failure of the only available battery charger must be assumed under the single failure criterion).

Note that most closing spring charging motors on safety-related breakers would not normally be required to operate at reduced voltage because in most design basis event scenarios, e.g., LOOP-LOCA, charging motors, which operate immediately after closing in most cases, would have already recharged their breakers' closing springs upon the initial closing after the vital bus(s) (and hence the battery chargers) have been re-energized on the standby emergency ac power source (e.g., a diesel generator). Even in the LOCA followed by a delayed LOOP scenario, which is not within the design basis of most plants, the charging motors of emergency core cooling system (ECCS) breakers would operate after their breakers closed upon ECCS initiation while normal power was still available. They would not need to operate again to allow their breakers to open upon loss of power and reclose one time as ECCS loads are automatically reenergized by, for example, an emergency diesel generator) load sequencer. Nevertheless, there may be certain instances that could require a charging motor to operate at reduced voltage (unless manual recharging is being relied upon). For example, during recovery from station blackout, if the EDG breaker or first offsite power supply breaker should fail to latch closed, and/or remain closed on the first try, the motor would need to operate at whatever control voltage was available to recharge the closing spring for subsequent attempts at closing, if warranted. While the motor would then operate at lower than normal speed, manufacturers, e.g., General Electric, have said that it is not deleterious for them to be tested at reduced voltage if deemed necessary.

Insulation resistance testing was being performed at some plants using inappropriate test voltage. Often the acceptance criteria required that the resistance be higher than some minimal value such as a thumb rule taken from rotating machinery testing practice, which is one megohm/(kV) + 1megohm. However, having a very high value (e.g., 1000 megohms, or more, @ 2500 volts-dc for 5-kV equipment, as recommended by the National Electrical Testing Association[1]) as an acceptance criterion (with results below this level requiring some action such as notifying the maintenance manager or cleaning) could facilitate early identification and timely correction of a degrading trend before a breaker failed to meet the minimum acceptable value. Also, some licensees did not require technicians to record the actual values measured, but only required them to indicate that the resistance was greater than some acceptance value, which as previously stated, was often too low. This practice was not conducive to meaningful data recording and evaluation of insulation performance and degradation.

III. <u>Corrective Maintenance</u>

Procedures or guidance to aid control room personnel who might have to deal with various types of breaker failures in the various modes of plant operation could prove useful. Although it may not be practical to develop detailed procedures for such failures, some general guidance on how to cope with failures of important breakers could be developed. Such predetermined operational

[1] National Electrical Testing Association Maintenance and Testing Specifications for Electric Power Distribution Systems and Equipment, MTS-1989.

considerations and off-normal operating guidance could be very helpful to operators, both from the standpoint of facilitating promptly placing the plant in a safe and stable condition and, to the extent possible at the same time, permitting the isolation of the affected breaker in order to preserve the as-failed conditions. For example, some plants have experienced failures of breakers to open (or open fully) on demand, a much less common, but typically more complicated problem than failures to close. Having predetermined off-normal operating guidance for this contingency could have minimized the time the affected plants had to remain in an unanalyzed condition while operators formulated the strategy for coping with the situation. In one case, having the coping strategies for a stuck-closed residual heat removal (RHR) pump breaker thought out ahead of time might have provided additional time for consideration before an unplanned plant shutdown was deemed necessary. In this case, knowing how much excess initial load the emergency diesel generator (EDG) could actually handle safely (because one of the subsequent automatically sequenced loads, the RHR pump, could not be disconnected from the affected vital bus), might have obviated the need to declare the emergency diesel generator inoperable, at least initially. Knowing how long it was actually safe to run the affected pump on minimum recirculation flow if, for instance, local temperatures or other parameters could be monitored, could have enabled operators to easily and promptly determine how much time was available to shift loads, lock out alternate sources, and de-energize the affected bus, so that some inappropriate and ineffective measures to open the breaker with the bus energized under time pressure (which resulted in damage to the breaker and violation of personnel electrical safety precautions) might have been avoided.

Procedures or guidance covering isolation, quarantining, and troubleshooting of failed circuit breakers by local visual examination, documentation (logging), and evaluation of the state of indications or the transitions observed in indications, or carefully documenting as-found conditions could be useful. Few licensees have developed symptom-based breaker troubleshooting plans to aid in determining the root causes of failure. Although such procedures are not explicitly required by NRC regulations, they could facilitate failure analysis and corrective actions, while minimizing the time that the electrical distribution system may have to remain in an abnormal lineup. For example, such plans might include predetermined strategies to determine the actual position of the contacts, the state of the closing spring, the state of the tripping or closing (or closing spring release) latches; to determine whether an opening or closing operation was electrically initiated, whether the breaker's failure to open, close, or remain closed (i.e., if it went "trip free") on demand was mechanical, or whether there might have been an electrical failure such that the closing or opening sequence was never initiated. In the past, instead of performing logical, coordinated failure analysis, some licensees performed routine preventive maintenance on a failed breaker and, if successful, placed the breaker back in service, only to have it, or another breaker in a similar condition, fail for the same, still undetected reason at a later time.

A knowledgeable and experienced breaker technician may be able to identify factors contributing to a failure from just a visual examination of the breaker in its cubicle or cell, but may not always be readily available. However, most on-duty technicians should be able to make basic determinations aided by a well-thought-out troubleshooting guide. Once the breaker is disturbed or removed from the cell, valuable information may be lost. Also, being aware of the latest industry operating experience or vendor information can be very useful in troubleshooting efforts. Certain contributing factors can sometimes be easily verified or discounted if the technician is alerted to the various problems identified by previous failures in the industry or at a specific plant.

Some licensees have developed (or contracted for) special diagnostic techniques, such as video boroscopy; high-speed videography; and time, motion and current data recording. These techniques have proven invaluable in analyses of certain unusual breaker failures when problems were intermittent and routine inspections and tests were inconclusive or ineffective in revealing the root causes. Such special techniques would not be expected to be employed routinely, but in several cases they have been the only methods that were successful in identifying the cause of the failure.

IV. Licensee/Vendor Interface

Licensees committed to implement vendor interface programs to address Item 2.2 of Generic Letter 83-28, "Required Actions Based on Generic Implications of Salem ATWS Events," issued July 8, 1983, and later, GL 90-03, "Relaxation of Staff Position in Generic Letter 83-28," Item 2.2, Part 2, "Vendor Interface for Safety-Related Components," issued March 20, 1990. The purpose of vendor interface programs, as stated in GL 90-03 was to ensure that licensees would receive all vendor technical manual updates or revisions in a timely manner and also all other relevant technical information in order to have the latest applicable information with which to operate and maintain the key safety-related equipment . Inspection results indicate that several aspects of licensee/vendor interface programs could be improved.

Circuit breaker and switchgear vendor manuals should be maintained current by periodically recontacting the vendor (by telephone) to ensure that the licensee has the latest vendor information, including updates to manuals, or other pertinent technical information bulletins, letters, and so on. In the past, some licensee recontact efforts have not been successful because of reorganizations, or name and location changes of several switchgear manufacturers, or by vendors who were unresponsive to periodic recontact attempts and requests for information by licensees. In the past year, however, the major circuit breaker vendors have begun participating in the EPRI/NMAC circuit breaker users groups and the licensee/vendor relationship appears to be improving.

Several licensee circuit breaker vendor interface program weaknesses were identified during NRC inspections, including (1) uncoordinated or conflicting procedures; (2) inaccurate or incomplete lists of key safety-related components; (3) inaccurate, incomplete, or out-of-date lists of vendor names and/or locations and cognizant personnel or the most appropriate contacts; (4) insufficiently detailed or specific periodic recontact form letters requesting information, often not sent to the most appropriate vendor department, location, or personnel; (5) insufficient followup on requests for information; (6) insufficient involvement by technically knowledgeable personnel; (7) organizational weaknesses, such as lack of priority, lack of centralized responsibility, and having separate distribution paths; or (8) poor administration.

Some licensee-identified areas of vendor interface program improvements include (1) periodic review of plant equipment to ensure that lists of key safety-related equipment are current; (2) establishing organizational and procedural interfaces and links to ensure that vendor interface personnel are kept informed of equipment changes or modifications; (3) establishing personal contact with the cognizant or most appropriate vendor personnel with the ability and willingness to provide the licensee with the needed information in a timely manner; (4) substantial involvement in the process by personnel technically knowledgeable of the equipment and well acquainted with vendors' technical documentation and staff contacts; and (5) periodic comprehensive reconciliation with the vendor of lists of equipment and related technical publications or documentation, preferably by telephone and followup correspondence.

V. <u>Control Voltage Calculations</u>

As part of their implementation of NRC regulations, including General Design Criterion (GDC) 17, "*Electric Power Systems*" and GDC-18, *"Inspection and Testing of Electric Power Systems,"* of 10 CFR Part 50, Appendix A; 10 CFR 50.63, "Loss of all alternating current power;" and Criterion III, "Design Control," of 10 CFR Part 50, Appendix B, many licensees have performed calculations to determine the worst-case design-basis control voltage (nominally 125 Vdc) available at the trip solenoids, closing solenoids, or closing spring release solenoids on safety-related circuit breakers as part of the design basis of the vital electrical power distribution systems. These calculations have sometimes been performed in conjunction with sizing or capacity calculations for vital station batteries, and in conjunction with the development of station blackout coping analysis.

In some cases, although formal rigorous calculations for each circuit were not performed based on actual installed cabling, design engineers established the minimum allowable breaker control voltage for the plant as the vendor-specified minimum operating control voltage for the trip and closing solenoids. To translate this design basis requirement into design constraints for construction, they first assumed minimum source voltage (e.g., minimum vital station battery voltage without chargers, typically around 105 Vdc), then calculated the allowable maximum lengths and allowable minimum sizes for control cabling. During construction, when it became difficult to meet these design requirements in certain cable installations, some licensees used interposing (boosting) relays or used parallel current paths to reduce line resistance and hence minimize voltage drop to meet the design basis requirement that no less than the vendor-specified minimum solenoid voltage would be available to trip and close safety-related breakers.

However, the NRC inspections revealed that a few licensees had neither performed the calculations based on as-built systems, nor enforced alternative design constraints during construction. Several discrepancies were identified in licensee calculations, including: (1) not starting with the minimum battery voltage; (2) using an incorrect minimum battery voltage that did not take into account loading, state of discharge, and/or aging factors; (3) using incorrect current paths, cable lengths, conductor sizes, and/or ohms/foot values to determine overall cable resistance; (4) calculation of cable conductor resistance using ambient temperature values, but neglecting temperature rise due to heat from surrounding cables in a raceway or without having data to justify the non-conservative lower temperature assumption; and (5) using incorrect loading values in the final determinations of voltage drops.

VI. Operating Experience Review

Operating experience review programs should review applicable documents from all pertinent sources. These documents include NRC information notices (INs); INPO SEE-IN documents or Nuclear Network reports; and vendor information, such as service information letters (SILs) from General Electric (GE) Nuclear Energy, service advice letters (SALs) from GE product departments such as the former Specialty Breaker Plant (for Magne-Blast equipment) or GE Electrical Distribution and Control (for low-voltage switchgear equipment); and technical bulletins or nuclear service advisory letters (NSALs) from Westinghouse Nuclear Service Division or its predecessors.

This operating experience sometimes has not been reflected in licensee maintenance procedures for various administrative reasons, including that the information was not distributed to the appropriate licensee personnel or was not received by the plant at all.

However, in most cases, the greater problem involved incorrect determinations of applicability. The TI inspections revealed instances of industry operating experience information erroneously determined to be not applicable because of narrowly focused and/or superficial reviews and insufficient involvement by technically knowledgeable personnel. Problems generically applicable to several types of breakers were often not recognized because the plant's breakers did not have the same exact model designation as the one used as an example in the information notice or the vendor technical bulletin. In some cases, licensees failed to recognize specific applicability because reviewers were not familiar with their plant's equipment, did not perform adequate verification of installed equipment, or did not consult with more knowledgeable staff.

TI 2515/137, Revision 1, lists 62 NRC information notices and bulletins that deal with problems with low- and medium-voltage power circuit breakers. As many as one third of these were erroneously determined not to be applicable at one or more plants. Some examples of INs that were misclassified or received inadequate licensee review serve to illustrate this point.

IN 83-50, “Failures of Class 1E Safety-Related Switchgear Circuit Breakers,” issued August 1, 1983, alerted licensees to the failure of breakers to close on demand after racking to the connected position. This IN emphasized problems with breaker-cubicle electrical interlocks and interfaces, but the message was generically applicable. Superficial review and disposition of this IN often resulted in lack of procedural steps in post-maintenance test instructions or operations department instructions, as discussed previously, to ensure that electrical and mechanical breaker-cubicle interlocks and interfaces have been restored (such as by functionally testing breakers whenever they are returned to the connected position, plant conditions permitting).

IN 84-46, “Circuit Breaker Position Verification,” issued June 13, 1984, dealt with position verification of racked-in breakers. The breaker used as an example of the problem was a predecessor of the widely used 4.16-kV ITE/ABB type breaker now known by the “HK” designation, but the IN described it by its old ITE designation, “ITE Model 3.” Use of the older nomenclature apparently led to several licensees’ not realizing that they actually had breakers of the type discussed. In addition, several more licensees failed to realize that the problem and similar remedies were applicable to other types of breakers as well.

IN 90-41, “Potential Failure of General Electric Magne-Blast Circuit Breakers and AK Circuit Breakers,” issued June 12, 1990, alerted licensees to failures of GE Magne-Blast (Type AM, vertical lift) breakers due to deteriorated Teflon®-impregnated fiberglass “Tufloc®” sleeve bearings in their Type ML-13 operating mechanisms. The IN did not point out that this problem was also applicable to Type AMH, horizontal drawout, Magne-Blasts with Type ML-13A mechanisms; nor did the subsequently issued GE SAL 318 series; because the internals of the ML-13 and ML-13A mechanisms are the same. Some licensees with AMH breakers assumed the IN and SAL were not applicable to them and did not attempt to verify that assumption with the vendor or the NRC.

IN 93-85, “Problems with X-Relays in DB- and DHB-Type Circuit Breakers Manufactured by Westinghouse,” issued October 20, 1993, addressed a problem with sticking of the “X” or anti-pump relay used on some Westinghouse type low-voltage breakers. The IN used the Type DB-25 as an example because that was the model of breaker that failed and prompted issuance of the IN. The same type of relay is also used on Type DB-50 breakers. Some licensees with DB-50 breakers erroneously dismissed the IN as inapplicable, because the IN only mentioned the DB-25 breaker.

IN 97-53, “Circuit Breakers Left Racked Out in Non-Seismically Qualified Positions,” issued on July 18, 1997, discussed the potential for some safety related breakers to be left in the racked out position, which could affect the seismic qualification of both the breaker and the switchgear.

Some licensees did not properly evaluate the notice for applicability because no specific circuit breaker type or model numbers were given.

VII. Refurbishment

Some of the plants inspected did not have a schedule for breaker refurbishment (overhaul), even though the breakers had been in service for 15 to 20 years. Not all circuit breaker manufacturers have promulgated recommended time-based or operation-based refurbishment intervals or condition-based refurbishment guidelines, particularly for relatively less severe service conditions such as in nuclear power plants. However, industry experience indicates that generally, breaker performance begins to degrade after 12 to 15 years of service. Depending on the operating environment and the maintenance history, a particular breaker may need refurbishment either earlier or later than this range of service. At one plant that had a refurbishment schedule in place, not all applicable circuit breakers (in particular, dc supply breakers) were included in the schedule.

Refurbishments are accomplished by service shops affiliated with the original equipment manufacturer (OEM), independent (so-called third-party) contractors, or by licensees themselves, sometimes with outside assistance and/or training. Factors to be considered when choosing the most appropriate and expeditious means of refurbishment include: (1) OEM-affiliated facilities may have the most experience at servicing their particular brand of breaker, may have access to original design and manufacturing information, and may have the greatest ability to obtain genuine spare parts, but the cost may be higher and the OEM may not be able to meet a licensee's schedule if multiple refurbishments are needed in a short period of time; (2) a third-party contractor may be able to service breakers faster and at a lower cost but may not have fully qualified, experienced personnel for a particular type of breaker or may not have access to all of the original design information (which is a significant disadvantage when commercial-grade spare parts must be dedicated), and some third-party refurbishers have had difficulty obtaining OEM parts in a timely manner; nevertheless, some third-party refurbishers have developed elaborate reverse engineering processes, supplemented by extensive functional testing to compensate for their lack of original design data, and may be able to perform satisfactory dedications and refurbishments; and (3) in-house refurbishment may be the most cost-effective and it gives the licensee the most control over the process, but it may not be feasible for a licensee to allocate enough maintenance staff resources to keep up with the demand; in addition, licensee personnel (particularly considering turnover) may not perform refurbishments often enough to maintain proficiency and may require retraining by experienced contractor or OEM personnel.

Some licensees that have breaker refurbishments performed by OEM-affiliated service shops or by independent contractors, whether at the vendors' facilities or at the plant site, have found it helpful to have one or more of their own knowledgeable personnel observe the work, particularly the first time it is performed. Observation by licensee personnel can help ensure that the work is performed in accordance with the licensee's specifications.

Another area where the refurbishment process can be improved is the quality of the procurement documentation. Some purchase orders (POs) from licensees to the refurbisher simply stated that the breakers were to be refurbished, instead of prescribing detailed specifications for the work to be performed. Best results were obtained when technical and quality requirements were discussed in detail by the licensee and the refurbisher ahead of time, and then specified in the procurement documents or by reference to vendor proposals, licensee-approved vendor overhaul procedures, and so on. Effective POs also specified any agreed-upon modifications and upgrades, contents of condition and overhaul reports, disposition of old parts, and the licensee's quality release and/or receipt inspection acceptance criteria.

VIII. Maintenance Rule

The TI inspection results indicated that the scoping of breakers met the requirements of the maintenance rule. At most plants, in-scope breakers were classified in two categories: (1) incoming or feeder breakers, source output breakers, bus tie breakers, and supply breakers to transformers for lower voltage distribution buses were classified as part of one of the electrical power distribution systems, for example, the 4.16-kV vital system or the 480-volt shutdown boards, and (2) breakers that supply power to individual load equipment or motor control centers associated with a particular functional system (e.g., the residual heat removal system), the service water system, or the emergency diesel generator support system, were counted as part of that system. In some cases, a source output breaker might be counted as part of the source system (e.g., the diesel generator) as well as part of the connected distribution system.

In most instances, functional failures and maintenance-preventable functional failures were appropriately identified, and classified, and the affected system was shifted to a monitoring status under 10 CFR 50.65(a)(1) when warranted. However, there were some instances where multiple failures of similar types of breakers for similar reasons occurred within one year, but because the breakers were in different systems, and because one failure in each of those systems in a one year period did not exceed the licensee's established system reliability and availability criteria for demonstrating the effectiveness of preventive maintenance under 10 CFR 50.65(a)(2), the failures did not result in the placement of the affected systems in a 10 CFR 50.65(a)(1) status. Not shifting to 10 CFR 50.65(a)(1) status in these instances may have been appropriate for the system because the breaker failure would not typically be related to any attribute of the plant system, with the possible exception that some systems, by the nature of their operational modes, cause their associated breakers to be cycled more than others. However, the multiple, and sometimes common-cause, breaker failures did not result in the increased scrutiny and higher priority attention afforded by 10 CFR 50.65(a)(1) status.

To address this type of situation, some licensees established circuit breakers of similar types as separate classes of components across system boundaries in addition to their conventional classifications. This practice allowed the reliability and availability of similar types of breakers to be tracked at the "component type" level, independent of their load or distribution systems so that in the event of multiple and/or common-cause functional failures (some of which might be "maintenance preventable"), the affected class of breakers could be evaluated for monitoring under 10 CFR 50.65(a)(1), if warranted. Grouping circuit breakers as a separate class of components could aid in performing root cause evaluations (particularly if deficient maintenance was implicated) and also aid in formulating effective and comprehensive corrective action because other failures of breakers of the same type might have previously been attributed to a similar problem.

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Attachment C – Lubricant Self-Life Guidance

Excerpt from EPRI NP-4916-R2, *NMAC Lubrication Guide,* Revision 2, Section 3.2. February, 1995.

Section 3.2 Shelf Life

In general, lubricants are very stable when exposed to the mild conditions encountered in storage or "on the shelf." Storage life of many years should result. This assumes, of course, no exposure to rain, sunlight, or sources of heat such as adjacent steam lines. Why then do suppliers often limit recommended shelf life to about two years? For several reasons:

- Formulations change from time to time for supply and performance reasons - base oil changes, additive changes, etc. Incompatibility between old and new versions sometimes is a problem. Storage life restrictions limit the supplier's responsibility for old formulations

- Conditions of storage can vary widely and some deterioration can take place under situations over which the supplier has no control. For example:

    - If an oil were frozen, i.e., cooled below its pour point, the solubilities of its additives could change. In an extreme case, a part of the additive package could drop out of solution and perhaps not re-dissolve upon return to normal ambient temperature. Such an event would be rare.

- With greases, some cosmetic (but mostly non functional) changes can take place. These relate to the problems described in Section 3.4, Continuous Versus Intermittent Use. For example:

    - Age hardening, i.e., hardening during the first few months of life. This occurs mostly with soft greases - consistency generally recovers on working.

    - Surface color change

    - Surface cracking from shrinking on cooling after manufacture or on heating and cooling in storage.

    - Bleeding, or oil separation. The separated oil can be decanted or stirred back in; it is only a small portion of the total. This occurs mostly with soft greases made with low viscosity oils. A small amount of bleeding is accepatable. (See ASTM D 1742 for perspective.)

Suppliers' reluctance to sanction extended shelf life is understandable.
Although lubricant changes in storage are mostly cosmetic, they can be sources of many complaints. However, attention to storage conditions (including those for drums), e.g, avoidance of temperature and other environmental extremes, will eliminate virtually all the potential problems. A few simple test,s e.g., sensory tests and infrared (see Sections 4.3, "Lubricant Testing") on the questionable lubricants vs. an authentic sample will give confidence that stored material is still acceptable.

Attachment D – NETA Recommended Minimum Insulation Resistance

The National Electrical Testing Association's (NETA*) Maintenance and Testing Specifications for Electrical Power Distribution Equipment and Systems* (NETA, MTS-1997) provides switchgear insulation resistance test voltages and minimum insulation resistance (in Megohms). (Table 10.1 in MTS-1997). The table from NETA MTS-1997 is provided below.

Voltage Rating	Minimum dc Test Voltage	Recommended Minimum Insulation Resistance in Megohms
0-250	500	50
251-600	1000	100
601-5000	2500	1000
5001-15000	2500	5000
15001-25000	5000	20000

Attachment E – Example Self Assessment Tasks, Objectives, and Criteria

The following is provided as an example circuit breaker self-assessment tasks, objectives, and criteria.

1) Verify the Program Owner(s) are qualified.

2) Verify Program requirements are communicated to appropriate organizations/personnel by way of a plant programmatic instruction.

3) Review other site programs, like the SI, PM, and M&TE that support the program where applicable.

4) Verify the program adequately addresses vendor/industry recommendations.

5) Verify periodic assessments are being performed.

6) Verify long standing and recurring medium and low voltage circuit breakers problems are being addressed.

7) Verify failures are trended, corrective actions are taken where appropriate and documented history for trending purposes exist.

8) Verify plant experience is factored into the program for improving medium voltage circuit breakers reliability.

9) Verify performance of the medium and low voltage circuit breakers (s) compared with medium and low voltage circuit breakers at other utilities.

10) Verify the program owner provides input into the outage schedules.

11) Verify the program includes contingency plans.

12) Verify the program supports the Maintenance Rule.

13) Verify there is a data-base available that includes the medium and low voltage circuit breakers and is it adequate for managing medium and low voltage circuit breakers quality and complexity.

14) Verify adequate procedures exist for maintaining, testing, and trending of the medium and low voltage circuit breakers. Verify industry lessons learned incorporated into procedures, including INs, SALs, technical bulletins, OEM advisories, and industry experience. Verify procedures incorporate lubrication of operating mechanisms,

lubrication frequencies, checks contacts, arc chutes, mechanical parts, auxiliary equipment, cell joints, cell contacts, breaker operation at minimum voltage, and insulation resistance.

15) Verify that the PM deferral status of the medium and low voltage circuit breakers is not outside accepted guidelines.

16) Verify the training program supports maintenance, testing and trending of the medium and low voltage circuit breakers.

17) Verify the planning organization adequately plan work for the medium and low voltage circuit breakers.

18) Review the history of unplanned outages related to failure of the medium and low voltage circuit breakers for negative trends.

19) Verify that the available spare parts are adequate to support the medium and low voltage circuit breakers maintenance program.

20) Review the site WO status for the medium and low voltage circuit breakers and determine if the backlog is within accepted guidelines.

21) Verify that good practices are communicated between sites.

22) Verify adequate tools are available for maintaining and testing the medium voltage circuit breakers.

23) Verify commercial parts used are dedicated properly.

24) Verify the vendor is contacted periodically.

25) Verify low voltage power system calculations support the reduced control voltage testing performed on the medium and low voltage circuit breaker.

26) Verify the response to SOER 98-02, “Circuit Breaker Reliability”, adequately address the outlined recommendations.

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EPRI creates science and technology solutions for the global energy and energy services industry. U.S. electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 1000 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems.

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