Operating Experience Smart Sample (OpESS) FY 2009-01
Inspection of Electrical Connections for
(Motor Control Center, Circuit Breakers, and Interfaces)

Highlighted documents have an active hyperlink.

OBJECTIVE:
To support NRC inspector's review of safety related Motor Control Centers (MCC). This OpESS provides additional information for inspection of the preventive maintenance programs at nuclear power plants. This OpESS is a voluntary inspection activity performed under the Reactor Oversight Process baseline program.

APPLICABILITY: All licensed operating commercial nuclear reactors with safety related motor control centers, cubicles, circuit breakers, and interfaces. Use this OpESS if there are indications of circuit breaker issues, the licensee is in the process of replacing, or upgrading their safety related circuit breakers.

BACKGROUND:
Based on the recent information and several electrical stab failures in motor control centers, the Operating Experience Branch recommended development of an aid to inspectors in the inspection of preventive maintenance programs, specifically for electrical connections like stabs and bolted electrical bus bars in motor control centers. This Operating Experience Smart Sample (OpESS) focuses inspector attention in the area of electrical connections. Additional information is included for interfaces between the MCC and circuit breaker (CB). The interfaces include circuit breaker stabs and mechanism operated cell (MOC) switch and electrical fingers that supply control power to the circuit breaker.

NRR staff review of recent operating experience related to motor control center failures have identified failures of aluminum buses using electrical type stabs connections and circuit breaker interface issues. The stabs are typically part of the circuit breaker and buses are integral to the MCC. NRR staff continues to review MCC and CB interface issues.

The recent MCC findings generally involved the failure to implement adequate corrective actions, the failure to ensure adequate procedures are available to perform maintenance, or the failure to follow procedures.

LESSONS LEARNED: PREVENTIVE MAINTENANCE PROCEDURES

Preventive Maintenance (PM) procedures should provide guidance for inspecting, cleaning, & appropriate lubrication of bus/stab connections for motor control centers. In Figure 1 shown below is simplified stab and vertical bus bar cross sectional view with the stab in contact the vertical bus.

PM procedures should include visual inspection of the plating for stab and vertical buses at the point of engagement between the stab and vertical bus. If the plating has worn off exposing bare metal, then clear direction should be given in the PM procedure to correct the deficiency. PM procedures should also verify breaker stab tension. Stab tension should be sufficient to handle all rated and fault currents. Some licensees have replaced the existing stabs with longer or double stabs. The point of contact between the stab

and vertical bus is crucial for licensees to inspect. Oxidation of silver plating over time can reduce the electrical connection properties. Over heating and failure of the electrical connections can occur without adequate preventive maintenance. Based on a review of the design for existing stabs on high risk motor control center cubicles, at least two licensees have added another set of stabs for large motor loads (50 Hp and above).

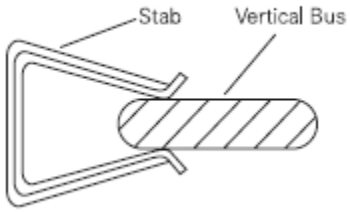

Figure 1 Sketch of Stab & Vertical Electrical Bus

The stabs rating should adequately handle the short circuit rating for the motor control center. This rating varies due to several factors but a typical 480-volt motor control center short circuit rating can be 22,000 amperes. The circuit breaker stab design should be adequate to handle this short circuit rating as well as the inrush current rating of the connected motor load. A typical 50 hp motor full load current can be as much as 65 amperes. The inrush current for this motor can exceed six times the full load current. The inrush current could exceed 390 amperes. ANSI standards for motor control centers provide short-circuit acceptance criteria that the "Stabs and vertical buses at the point of contact shall be in essentially the same mechanical and electrical condition as before the test". This criterion highlights the importance of good electrical connection, allowing 22,000 amperes to pass thru the stab without damage.

Some licensees have replaced aluminum bus bars with copper to minimize high resistance stab connections. Aluminum bus bars plating worn or scraped due to multiple insertions and removals of the circuit breaker will oxidize.

LESSON LEARNED: ELECTRICAL CONNECTIONS

A Special Inspection began at San Onofre Nuclear Generating Station on August 4, 2008 in response to the identification of deficient electrical connections. The deficient electrical connections potentially could adversely affect the safety function of multiple safety systems used for accident mitigation.

One example referenced in the inspection charter was EN 41798 - San Onofre 3- EDG INOPERABLE DUE TO LOOSE ELECTRICAL CONNECTION. The licensee later retracted this event notification because the emergency diesel generator (EDG) was considered operable. The licensee submitted a voluntary licensee event report to document this event and inform the NRC of the corrective actions taken. To review this LER, click on the following link: Emergency Diesel Generator (EDG) 3G003 Declared Inoperable due to Loose Wiring Connection on Emergency Supply Fan.

LESSON LEARNED: INTERFACES BETWEEN CIRCUIT BREAKER & MOTOR CONTROL CENTER

The two events below give examples how CB and MCC cubicles need to interface properly to actuate the mechanism operated cell (MOC). The most recent example at Palisades indicates what can happen when the force exerted on the MOC is too large. The second example at Columbia Generating Station describes the effects of too little force on the MOC.

On March 26, 2008, at Palisades, the licensee was conducting planned maintenance on train "A" high pressure safety injection pump. A plant operator had experienced difficulty racking the breaker out, and during a visual inspection of the pump breaker and cubicle, the licensee found that a bayonet on the MOC shaft was bent and interfering with the CB. In addition, another bayonet on the same shaft had cracks on the brazing connecting it to the shaft. The licensee determined that a new CB installed from 1999 to 2004 exerted additional force on the MOC switch that may have exceeded the capabilities of the brazed joint. At the time, the licensee evaluated compatibility of the cubicle and breaker, but did not recognize that in the 1980s the manufacturer had strengthened the bayonet design to accommodate faster acting breakers. The stronger bayonet design was not installed in the site's existing breaker housings. The licensee inspected the MOC switches for the remaining safety-related breakers and identified no other examples that resulted in equipment inoperability. Until further upgrades are completed, the licensee will inspect safety-related breakers after operation to ensure the integrity of the mechanism. See LER 255/2008-02 Title: Breaker Cubicle Switch Failure Results in High Pressure Safety Injection Pump Inoperability

At Columbia Generating Station on February 14, 2002, Emergency Diesel Generator (EDG) 2 output circuit breaker closed but the MOC switch assembly failed to change state as expected. The licensee found the root cause of this problem was the original CB had provided more force to overcome the MOC linkage resistance. The upgraded CB did not provide enough force to overcome MOC linkage resistance. See LER 397/2002-01 Title: Completion of Technical Specification Required Shutdown to Comply with Technical Specification LCO 3.8.1 Required Actions of Condition F

RECENT CIRCUIT BREAKER INSPECTIONS:

PILGRIM NUCLEAR POWER STATION – NRC COMPONENT DESIGN BASES INSPECTION REPORT 293/2008-007

During a Component Design Bases Inspection (CDBI) at Pilgrim, the CDBI team identified a finding of very low safety significance (Green). Elevated temperatures were identified on the 'B' 125 Volt direct current (Vdc) battery charger supply circuit breaker terminals during the performance of infrared thermography by the licensee on January 4, 2006. Later testing by the licensee did not recognize lower electrical current flow would generate less heat and thermography would indicate the lower temperature results. On April 27, 2007, the licensee conducted a battery discharge test. The B' battery charger 480 Vac supply circuit breaker tripped on over-current and subsequently failed while recharging of the 'B' battery.

FORT CALHOUN STATION - NRC SPECIAL INSPECTION REPORT 285/2007-006, Fort Calhoun – LER 285/2007-002 Common Mode Failure of Medium Voltage (4160) Circuit Breaker

Common Mode Failure of Medium Voltage (4160) Circuit Breaker occurred on January 25, 2007. The 4160 volt circuit breaker for raw water (RW) pump AC-10B closed on demand, but the auxiliary contacts did not actuate. On February 8, 2007, a similar event occurred where the circuit breaker for RW pump AC-10C closed on demand, but its auxiliary contact switch did not actuate. The failure was determined to be a broken mechanical linkage rod.

SOURCE DOCUMENTS:

Review the Background and Source Document Sections of this OpESS and the related documents as needed to obtain a general understanding of some of the various MCC concerns (i.e., failures of MCC stabs and failure to take prompt corrective action, especially related to post-maintenance testing, etc.).

NRC Information Notices and Circular:
IN 2007-34: Operating Experience Regarding Electrical Circuit Breakers

IN 2002-27: Recent Fires at Commercial Nuclear Power Plants in the United States

IN 2000-14: Non-Vital Bus Fault Leads To Fire and Loss of Offsite Power

IN 88-11: Potential Loss of Motor Control Center and/Or Switchboard Function Due To Faulty Tie Bolts

CIRCULAR 77-03: Fire Inside A Motor Control Center

INSPECTION FINDINGS: ELECTRICAL CONNECTIONS

The following link provides inspection findings to highlight previous electrical connection issues: Electrical Connection Findings (4 Green Findings, 12 Green NonCited Violations, and 1 White Violation)

Docket	Inspection Report	Licensee Site	Finding
05000353	2008002	Limerick	Green
05000278	2007003	Peach Bottom	Green
05000275	2004004	Diablo Canyon	Green
05000390	2003002	Watts Bar	Green

Docket	Inspection Report	Licensee Site	NonCited Violation
05000293	2008007	Pilgrim	Green
05000277	2008007	Peach Bottom	Green

05000498	2008003	South Texas Project	Green
05000368	2007009	Arkansas Nuclear One	Green
05000443	2007005	Seabrook	Green
05000255	2006009	Palisades	Green
05000440	2005009	Perry	Green
05000269 05000270 05000287	2005004	Oconee	Green
05000354	2004002	Hope Creek	Green
05000443	2002005	Seabrook	Green
05000298	2001008	Cooper	Green
05000483	2000009	Callaway	Green

Docket	Inspection Report	Licensee Site	Violation
05000298	2008002	Cooper	White

BASELINE INSPECTION PROCEDURES:

Baseline inspection procedures can be used for performing this OpESS and can include inspection procedures used for performing inspections during surveillance testing, post maintenance testing, or PI&R corrective action follow-up inspections related to CB and MCC issues. Links to these base line procedures are provided in the section below.

IP 71111.12 - Maintenance Effectiveness

IP 71111.19 - Post Maintenance Testing

IP 71111.21 - Component Design Bases Inspection

IP 71111.22 - Surveillance Testing

IP 71152 - Identification and Resolution of Problems

INSPECTION GUIDANCE:

Review several electrical preventative maintenance procedures focusing on safety related circuit breaker procedures, special attention should be given to removal of electrical connections. Here is a list of questions to consider in reviewing the PM procedures.

1) Does the procedure inspect the cleanliness of the exposed connections and did the connection require anticorrosion lubricant?

2) Does the preventive maintenance procedure verify that the connection is adequately tight for the application?

3) Does the procedure verify the resistance measurements of the connection?

4) If the licensee has indications of higher than normal thermography readings, did they properly evaluate and take adequate corrective actions? See example finding documented under section 1R21.2.1.1 of Pilgrim Nuclear Power Station – NRC Component Design Bases Inspection Report 293/2008-007

5) Assess licensee effectiveness in identifying deficient electrical connection problems, evaluating the cause of these problems, and implementing corrective actions to resolve identified problems.

6) Assess the adequacy of licensee processes (procedures, maintenance instructions, training, etc.) for maintaining proper electrical connections.

7) If during a Component Design Bases Inspection using Appendix 2, Component Condition and Capability review circuit breaker modifications and consider if the modification included replacement of bus work for the circuit breaker? If existing bus work is in service, does the licensee inspect for wear?

Example: New bus bars for safety related batteries might have a different lubricant applied for shipping or storage. The lubricant may have excellent anticorrosion properties but poor electrical properties. The removal of the shipping grease, cleaning of the bus bar and applying the correct electrical anticorrosion grease should be included in the preventive maintenance / modification procedures.

REPORTING INSPECTION RESULTS / TIME CHARGES / ADDITIONAL ISSUES:

Document any inspection result findings, as applicable, in an integrated inspection report (i.e., quarterly inspection report) and reference the title and OpESS number (example: "**Review of Operating Experience Smart Sample (OpESS) FY 2009-01 Inspection of Electrical Connections for (Motor Control Center, Circuit Breakers and Interfaces)"**. If no findings are identified document completion of the OpESS using the "OpESS number/ title" under the applicable inspection attachment (i.e., 1R12,) stating that no findings of significance were identified.

Inspection time for this OpESS is to be charged to the normal baseline procedure under which it is being documented (along with any routine preparation and documentation charge times).

Note: This completes the OpESS inspection guidance. This inspection tool is voluntary for consideration by inspectors and can be updated or revised by providing feedback to NRR/ADRO/DIRS/IOEB to reflect the lessons learned by inspectors for improvement in knowledge transfer.