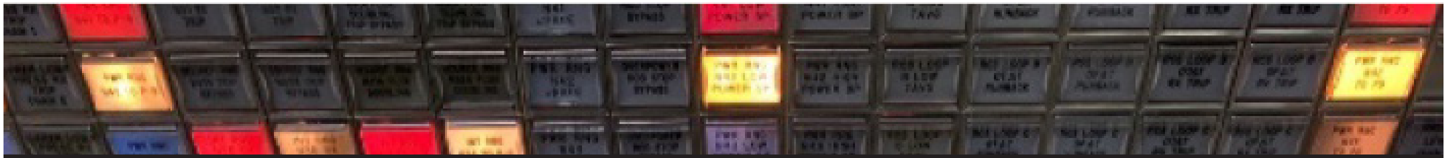
AVOIDING EQUIPMENT OUTAGES DUE TO CIRCUIT BREAKER INDICATING LIGHTS

November 2021



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Circuit breaker reliability helps ensure nuclear plant safe shutdown and protects the health and safety of the public. Operating experience has identified 18 equipment failures due to operators replacing indicating lights on circuit breakers powering operating equipment. This paper discusses this common failure mode and actions to prevent the loss of equipment important to plant safety and economic viability.

Failure Description

The red indicating light provides a visual indication that a circuit breaker is closed, power is being provided to the equipment, and there is a functioning trip circuit that will open a closed circuit breaker. If a circuit breaker is closed and the equipment is running, operators want to know that they have the ability to open the circuit breaker and remove the equipment from service, if necessary. The red indicating light on the control panel of a circuit breaker provides operators the confidence that a circuit breaker will function properly and can be opened (tripped).

Figure 1 illustrates a typical circuit breaker trip circuit. An illuminated red indicating light shows that:

- The circuit breaker is closed
- Control power is available to the control circuit
- There is a proper electrical connection through the circuit breaker's secondary disconnects
- There is a proper electrical connection through the circuit breaker's internal trip coil, auxiliary switch, and associated wiring
- There is a proper electrical connection through the circuit breaker's cell switch (if applicable)

When the circuit breaker is 'racked-in' (installed) and closed (the equipment or load is energized), the entire trip circuit should have proper electrical connection through it. When energized, there is always a small amount of current (about 0.1 amps) running through the trip coil via the local and control room red lights, both of which

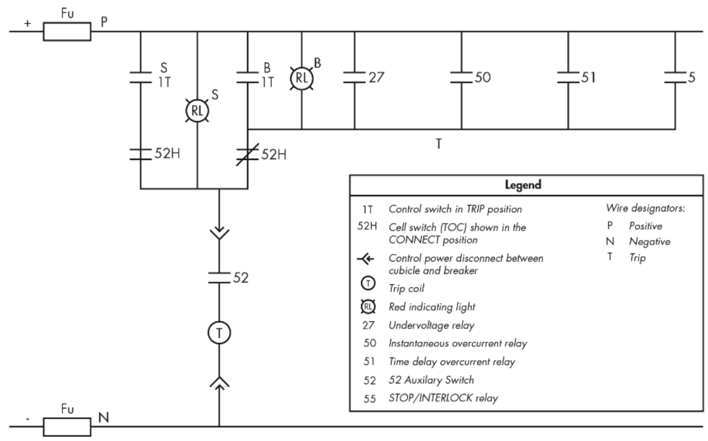
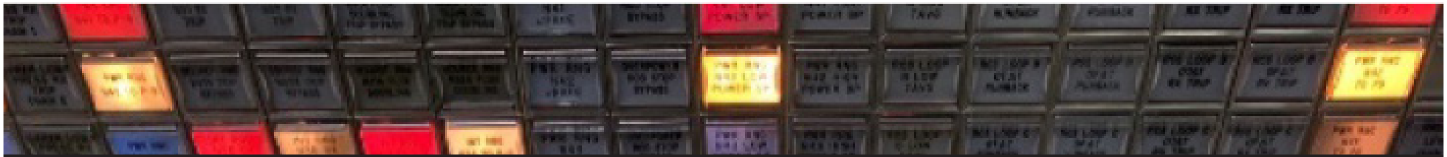


Figure 1 – Simplified Circuit Breaker Control Circuit

have resistive sockets or bulbs of several thousand ohms. The high-resistance bulb and socket combination is required to keep the voltage drop across the trip coil to a minimum. A typical circuit breaker trip coil ranges between 20-50 ohms for a 125V DC control circuit breaker. Because circuit breakers are designed to trip with about half of the control voltage present, the resistance of the remaining trip circuit must be kept many times greater than the 20-50-ohm trip coil except when it is desired to trip the circuit breaker. If the bulb and socket combination have a reduced resistance (shorted), the circuit breaker will trip. When the circuit breaker needs to open, a short circuit around the resistive light bulbs is applied via a relay or control switch contact and full voltage and current are applied, which provides sufficient current to actuate the trip coil. See Figure 1.

When a red indication light fails on a closed circuit breaker, operators have lost their indication that the circuit breaker can be tripped. Operators need confirmation that the circuit breaker will operate as intended. This functionality can be restored by replacing the light bulb with a light bulb that is verified to be operable. When replacing the red indicating light bulb on an energized circuit, there is some risk of tripping the circuit breaker. Replacing the red indicating light may reduce the resistance across the bulb and socket combination, thereby causing the circuit breaker to trip. Caution should be exercised, especially when a circuit breaker trip may cause a reactor scram, a turbine trip, a unit down-power, or entry into a Technical Specification Action Statement.

A similar failure, which is also common, can occur with light bulbs or bulb sockets on motor control circuits that typically results in a blown control power fuse.



Is the Trip Circuit Still Functional?

The trip circuit may still be functional when the red indicating light is not working, as all the other trip functions in the circuit operate in parallel to the light and are unaffected. A fuse failure may simultaneously disable the light and trip circuit. Refer to Figure 1, which shows a simplified circuit breaker control circuit.

Actions to Prevent Recurrence

There are actions that will "Confirm" the trip circuit is still operable without replacing the bulb. These methods could be used to avoid equipment failures due to red indicating lights:

- **Alternate Indication** – Many medium voltage circuit breaker designs also have indicating lights on the circuit breaker cubicle door that are in parallel to the Control Room red indicating lights. If available, the local red indicating light could be checked and, if illuminated, the circuit is functional.
- **Voltage Check** – If a local red indicating light is not available, a voltage reading could be taken at any convenient point along the T (trip) wire. See Figure 1. If approximately negative half of the DC Control Voltage with respect to ground is observed, the circuit is functional. If negative half Control voltage is not observed, the trip circuit is not functional, and the circuit breaker must be opened using local controls.

Once trip circuit operability is confirmed, replacement of the bulb can be planned at an opportune time. If the circuit breaker's load is run intermittently, bulb replacement could be postponed until the load is turned off.

Other strategies for reducing equipment failures due to red indicating lights:

- When replacing the indicating light bulb, ensure it is the exact same size, wattage, and resistance. Do not use excessive force or twist beyond the stopping point. Tighter is not better.
- For locally controlled loads, the red indicating lights could be removed from the circuit to eliminate the potential problem. See Figure 2.

Figure 2 – Warning sign on equipment controls

Operating Experience

A review of U.S. nuclear industry operating experience identified 18 failures of this type over a span of 20 years, resulting in a failure rate of about 1 per year. Common causes of these events include inserting the wrong size bulb into the socket, installing an incorrect bulb, installing a bulb into a cracked or damaged socket, and deteriorated sockets due to overheating, vibration, physical stress, or aging.

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