Property Risk Consulting Guidelines

X L Risk Consulting

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CONTROL POWER FOR ELECTRICAL SWITCHGEAR

INTRODUCTION

The purpose of this guideline is to highlight the importance of adequate and reliable control-circuit power supplies. Control-circuit power supplies are vital to the automatic operation of major electrical switchgear. Those responsible for loss control should assess the maintenance and supervision provided to such systems, and should pursue improvements in accordance with this guideline. Inattention to these systems can precipitate and magnify losses. Loss control personnel cannot be expected to judge the adequacy of control-circuit power, nor to make recommendations in this regard, as these responsibilities should be left to qualified electrical system design engineers.

In contrast with most low voltage (to 600 V) circuit breakers where thermal or magnetic overcurrent sensing devices directly actuate the tripping mechanism to a latch release for operation of the breaker, many medium and high voltage power circuit breakers are actuated electrically through a control circuit. These power circuit breakers cannot operate without a control-circuit power supply. Often, battery rooms supply control-circuit power.

When a control-circuit is impaired, the overcurrent protection of the electrical system is thus impaired. Electrical equipment connected to the system, e.g., transformers, turbogenerators, motors, and substations, are thereby vulnerable to serious damage in the event of subsequent electrical breakdown or lightning surges. Maintenance and supervision are needed to assure reliability of a control-circuit power system. This guideline assumes that only qualified personnel will perform maintenance on these systems, and that proper safety precautions will be followed in the application of recommendations.

POSITION

To assure reliability and adequate maintenance of control-power systems for medium and high voltage switchgear, the following is recommended:

- Maintain lead-acid control-power storage batteries and battery chargers in accordance with Subsection 11.14 and 15.9.4 of NFPA 70B. At least weekly, inspect the dc control-system to assure that the charger is operating correctly; the batteries are holding proper charge; the electrolyte levels in the batteries are correct; the electrolyte and cells are clear with minimal deposits or rings; the battery and charger terminal connectors are kept clean, tight, and free of corrosion; there are no cracks in cells nor leaking electrolyte; and the ambient temperature and ventilation are appropriate. Quarterly, record the specific gravity of each cell; the voltage of each cell; and the electrolyte temperature in selected cells using a minimum of one cell out of every eight cells. If infrared scanning equipment is available, scan battery terminals and intercell connectors quarterly for abnormal temperatures.

- Maintain nickel-cadmium control-power storage batteries and battery chargers as appropriate. At least weekly, inspect the dc control-system to assure that the charger is operating correctly; the batteries are holding proper charge; the electrolyte levels in the batteries are correct; the electrolyte and cells are clear with minimal deposits or rings; the battery and charger terminal connectors are kept clean, tight, and free of corrosion; there are no cracks in cells nor leaking electrolyte; and that ventilation is appropriate. Quarterly, record the voltage of each cell. If infrared scanning equipment is available, scan battery terminals and intercell connectors quarterly for abnormal temperatures.
- Locate batteries in a well ventilated area to avoid hydrogen accumulation; substantially support and secure batteries against displacement; determine that the batteries are not exposed to arcing, excessive heat, vibration, mechanical injury, or flooding; and verify that batteries are readily accessible for servicing and maintenance.
- Test any newly installed or renovated dc control-power system using an overcurrent-protected battery test-load circuit. Check that the tripping voltage and current of the dc source are sufficient for the maximum load in the tripping circuit, and meet design criteria. Also, conduct a discharge capacity proof test. Set schedules so that a discharge capacity performance test is repeated in the second year of operation, and then at no less than 5 year intervals, with the frequency increased to yearly when the batteries have reached 85% of their service life or show excessive capacity loss. Maintain records to compare the initial proof testing with subsequent performance tests through the life of the equipment. Replace batteries as recommended by the manufacturer following review of capacity test results.
- Electrically monitor the tripping circuit of the circuit breaker by supervising the electrical circuit between the dc battery and the trip coils of the circuit breakers. Also, supervise the output voltage of the battery charger on the load side of the dc overcurrent-protective-device. Send all signals to a constantly attended location.

DISCUSSION

Electrical switchgear encountered in yard substations, power houses, and switchgear rooms of large industrial plants commonly utilize dc control-circuits that are independent of the electrical system being protected. For reliability, the usual power supply to the dc control circuit is a wet-cell battery bank. Other types of supplies, such as step-down transformers and converters, may not function when power to the electrical system is lost.

Switchgear may be “power operated” for both opening and closing functions. Depending upon design, the power operators used to open and close circuit breakers may be dc or alternating current, although the former is preferred. Mechanical assists, such as pneumatic operators, self-stored spring power, or spring-assisted gravity mechanisms, are also commonly employed, particularly in the tripping function.

Regardless of where the power for the power operators comes from, or whether mechanical assists are employed, this type of power switchgear is still dependent on the control circuit for automatic operation. It is through the control circuit that “commands” to the circuit breaker are initiated; be it the actuation of a relay in the power operator circuit or the tripping of a mechanical assist.

Control power has two primary functions in the operation of power circuit breakers, closing power and tripping power. **Closing Power** is required to close a circuit breaker when it is energized or de-energized. Because closing power should be independent of ac voltage conditions in the power system associated with the circuit breaker, a dc battery supply is considered the most reliable.

Tripping Power is needed to energize the trip coil in order to trip open the power circuit breaker. Without tripping power, a power circuit breaker **cannot automatically open** the electrical circuit on a predetermined overcurrent. Because this tripping power is inherently vital to the protection of the electrical system, it must be available at all times to allow a circuit breaker to perform its protective function.

The dc control-power system should be capable of simultaneously supplying adequate tripping power (voltage and current) to all circuit breakers connected to the dc supply. Whenever additional loads are connected to the system, an electrical study of the dc control-power system should be made by a qualified electrical engineer to verify adequate tripping power.

There are two popular methods of supplying tripping power to the trip coil, storage batteries and charged capacitors. A properly maintained **Battery Supply** is considered the most reliable tripping source. Since it is independent of ac power-circuit voltage conditions during faults, it is considered the best source for protective-relay tripping. Normally a 125 V battery supply is provided for tripping power. Where a 125 or 250 V battery supply is not available or cannot be justified, a 48 V supply may be used.

Occasionally, a **Charged Capacitor** is used to supply tripping power. A continual ac power source charges the capacitor used in the capacitor trip unit. Upon loss of ac control power, the standard capacitor trip will retain its charge for at least 30 seconds; but there are more sophisticated units that will retain sufficient tripping power for three days.

Control circuits to power-operated circuit breakers and related switchgear normally carry little or no load until called upon to energize the closing or tripping circuit of the breaker. Many branch circuits of the control system are actually not powered until an operating demand is impressed; for example, a call for a trip. Thus, if problems develop in the wiring or other components, they could go undetected. When called upon to function, the control circuit would fail. Such problems include broken wires, inadvertent grounds, short circuits between conductors, battery terminal corrosion, and individual battery cell failure. Also, loose connections and poor splices can cause excessive resistance when current flows, and can thus prevent powering the actuator mechanism. Proper maintenance and supervision are needed to assure system reliability.

Storage batteries and charging equipment that supply dc power to electrical switchgear are usually located in a battery room or in the corner of a building detached from the switchgear room, building, or substation. Occasionally storage batteries and charging equipment are located in the same room but mounted externally to the switchgear.

Normally, all the electrical switchgear at a site is supplied control power from a single dc control-power supply. In such cases, all of the circuit breakers throughout the facility, including the main transformer circuit breakers, tie circuit breakers, feeder circuit breakers, and branch circuit breakers, may be dependent upon this supply. Dependence upon a single dc control supply is not desirable since loss of this supply impairs the entire electrical protection system and thus increases the vulnerability to large loss involving transformers, turbogenerators, large motors, metal-clad switchgear, cable trays, etc.

To minimize losses in which extremely valuable or critical electrical equipment is involved, or where high business interruption potentials exist, connected reserve or back-up dc power supplies should be considered. Where provided, they should be detached and preferably located in separate fire areas. Acceptable redundant supplies include motor generator sets, rectifiers, exciter bus systems, and dual batteries.

Similarly, protection of electrical systems can be upgraded by reducing the overall dependence upon a single dc source. By de-centralizing the dc system into localized, independent systems, certain circuit breakers can operate independently.

De-centralization of a dc system or inclusion of a connected reserve dc power supply should only be done if approved by a qualified electrical engineer thoroughly familiar with the overall electrical system.

LOSS EXPERIENCE

AXA XL Risk Consulting has experienced large losses, some up to several million dollars, involving unreliable dc control-power supplies. Initiated by fire, explosion, lightning, or electrical breakdown and ensuing fire, each loss could have been lower had there been no control-power problems. For example:

- An electrical surge induced during a lightning storm ultimately damaged two, 93,000 ova oil insulated autotransformers located in the main electrical switch yard of a steel mill. One autotransformer would not have been damaged and the magnitude of the damage to the other reduced had the 69 kV in-plant circuit breakers opened during this incident. It was subsequently determined that the dc control batteries supplying tripping power to these breakers were not sufficiently charged.
- Loss of dc field excitation to two, 3000 hp, synchronous motors in a cement plant resulted in extensive electrical breakdown and ensuing fire. Both mill motors would not have been damaged had the circuit breakers to the 4.16 kV motor or the 138 kV transformer opened. The 20 ampere circuit breaker supplying the battery charger was found tripped open, explaining why the 125 V control battery system was charged to only 30 V. At least 100 V was required to open either the 4.16 kV or the 138 kV breaker.
- Electrical breakdown, ensuing fire, and/or explosion extensively damaged a paperworker's main transformers, substation, circuit breakers, cable trays, and raceways. This loss would not have occurred if the 48 V battery supply had been adequately maintained. Eleven of the thirty-six batteries were empty, and battery voltage was only 9.5 V. The operating range of the circuit breaker trip coils was 28 - 60 V.
- In a paper mill, one set of batteries supplied power to the rotor of a 6000 hp, 13.8 kV synchronous motor, and also to the control circuit for a circuit breaker feeding the ac power to the stator of this motor. Serious damaged occurred when the dc supply was lost. The circuit breaker could not open, and thus the ac supply to the synchronous motor could not be interrupted. The motor returned to the starting mode, as ac power continued to be available, and there was no dc to lock the motor in synchronism. Continuous operation of the motor in this mode caused rapid overheating, thermal stresses, and eventual electrical breakdown. Without dc power, the 13.8 kV circuit breaker was unable to clear the fault. Only when the main circuit breaker, with control power from another dc battery system, tripped, was the fault cleared.
- In a cement plant, extensive electrical arcing and ensuing fire severely damaged or destroyed three 1500 hp, 4.16 kV, synchronous mill motors; three cubicles of 4.16 kV switchgear; and hundreds of feet of 100 MCM power cable. Had the mill's 4.16 kV motor circuit breakers or the outdoor 69 kV circuit breakers operated, the equipment would have escaped with minimal, if not without, damage. An investigation of this loss revealed that the 4.16 kV and 69 kV breakers could not operate because the common 125 V control power supply was disconnected. Apparently, previous ground faults in the dc circuitry melted off one lug of the 125 V lead acid storage battery supply.
- Trouble began when a 13.8 kV, 350 MCM cable short-circuited inside a pit at a cable manufacturing plant. Failure of the 13.8 kV circuit breakers to open to clear the electrical fault damaged the oil circuit breakers and a line-side 600 kVA voltage regulating transformer. The 48 V lead acid storage batteries located in a steel cabinet in the switch yard that supply dc tripping power to the 13.8 kV breakers were found to be discharged. Because the batteries were not maintained, they were not capable of tripping the circuit breakers when the cable fault occurred.