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Automatic fast bus transfer has been the subject of endless technical papers over several decades. The "ideal" fast bus transfer action would transfer the load to the reserve source instantaneously on loss of normal supply, with no loss of power to the load. This is nearly achievable with the new generation of static transfer switches, but these switches are very costly, and there are significant limitations on short-circuit capabilities with the present static transfer switch systems. Thus, for the immediate future, the vast majority of bus transfer activity in large industrial facilities and in power generation plants will involve conventional circuit breakers in medium-voltage metal-clad switchgear.

Table 1 gives the dead bus times for GMSG circuit breakers, based on use of the optional "fast" trip coil used with the rated interrupting time of three cycles (50 ms).

Transfer time is an important system design consideration, and several aspects should be evaluated when designing the transfer scheme and in the selection of devices and settings:

1. If the reserve-source circuit breaker is given a close signal simultaneously with the trip signal to the normal-source circuit breaker, overlap can result if the reserve-source circuit breaker closes before the normal-source circuit breaker completes the interruption.

During the overlap time, fault current exposure increases dramatically and may exceed the interrupting capacity of the circuit breakers used. However, since the overlap period is short, many users feel that the likelihood of a fault during the overlap period is not sufficient to warrant use of circuit breakers with higher short-circuit interrupting ratings.

During the overlap period, if the normal source should fail, the normal source will become energized (backfed) from the reserve source, which may result in loss of both sources. Simultaneous signals, or a variant, historically have been commonly used for routine transfers. Users should carefully assess the risks associated with overlap during transfers initiated with simultaneous signals. Except for routine transfers, use of simultaneous close and trip signals is not recommended.

2. The transfer time should be short enough to avoid significant slowing of motors in order to avoid excessive motor inrush currents when the reserve source circuit breaker re-energizes the loads. This is important for a variety of reasons:

- When the normal source fails, the driven (motor) loads slow down and act as generators due to their inertia. As the motor slows, the back electromotive force (EMF) of the motor "slips" with respect to normal system voltage, producing a phase angle between the back EMF and the reserve source.

Fast bus transfer times for GMSG circuit breakers

Source of closing signal	Dead bus time, ms (cycles)	
	No arcing	With arcing
Simultaneous close and trip signals	22.5 ms to 39.5 ms 1.4 cycles to 2.4 cycles	11.5 ms to 33.5 ms 0.7 cycles to 2.0 cycles
Trip, then close, using standard 52b contact on normal-source circuit breaker to initiate closing of reserve-source circuit breaker	49.5 ms to 62.5 ms 3.0 cycles to 3.8 cycles	38.5 ms to 56.5 ms 2.3 cycles to 3.4 cycles

Table 1: Dead bus times for Siemens type GMSG circuit breakers (based on three-cycle rated interrupting time)

In the worst case, the motor back-EMF voltage can be 180 degrees out-of-phase with the system voltage. If the reserve-source circuit breaker closes when the two voltages are 180 degrees out-of-phase, the motor windings will be exposed to nearly double normal line-to-ground voltage. Since the motor torque is related to the square of the applied voltage, as much as four times normal torque can be applied to the motor shaft. This high level of torque may be sufficient to cause severe damage to the motor shaft.

- The inrush current will be very high and may exceed the locked-rotor current seen during a normal start of the motor. These high levels of current may cause thermal damage to the motor insulation, leading to premature failure of the winding insulation to ground.
- The very high inrush current may cause the protective relays to operate and thereby shut down the load. This defeats the purpose of the original transfer, which is to keep the plant running.
- The high inrush currents may lead to severe voltage sag on the reserve source, with the result that there may be inadequate torque to re-accelerate the motors. One or more of the motors may fail to re-accelerate, with the possibility of damage to the motor.

3. A scheme to implement fast bus transfer should never be implemented if the normal and reserve sources are not synchronized. If it is possible that the sources may not be in synchronism, a transfer scheme can be employed with a synchronism-check relay to prevent closing of the reserve-source circuit breaker if the two sources are out-of-phase beyond a defined limit.

4. If the two sources are not synchronized, or if the transfer cannot be completed quickly (say, within six cycles), the transfer should be delayed. A common scheme for controlling transfer under such conditions employs a voltage relay connected to the load bus to monitor residual bus voltage.

The rule of thumb is transfer is delayed until the residual bus voltage is no higher than 25 percent of normal system voltage. Experience in many systems has suggested that closing the reserve circuit breaker with 25 percent or less residual bus voltage will not result in excessive shock to the system.

The amount of time that will be needed for residual bus voltage to decline to 25 percent will vary according to the amount of motor load, motor type and associated inertia, but the order of magnitude is typically 5 seconds or so.

Footnotes:

- ¹ Assumes control voltage at rated value.
- ² Dead bus time (no arcing) is the time from contact part on the normal-source circuit breaker to contact make on the reserve-source circuit breaker.
- ³ Dead bus time (with arcing) is the time from the end of arcing (non-fault current) on the normal-source circuit breaker to contact make on the reserve-source circuit breaker.
- ⁴ Standard 52b contact is equivalent to a traditional "fast b" contact. The standard 52b contact closes approximately 4 ms prior to main contact part.
- ⁵ The upper and lower values consider the extremes of circuit breaker operating times, 52b contact timing variation and arcing time duration.

Certain kinds of process plants may be able to tolerate this length of outage, while many will not. For example, in large power generating stations, if fans or pumps slow down appreciably, the boiler may be pressure surged or a pump cavitated.

An alternative to the use of a residual bus voltage relay is to use a time delay relay to impose sufficient time for the residual voltage to decline to 25 percent or lower. One reason this alternative is popular is it eliminates the need for bus voltage transformers, and the time delay relay is somewhat less costly than a residual bus voltage relay.

5. The automatic transfer function should be disabled if a fault exists on the load bus, i.e., when the normal source circuit breaker is tripped by overcurrent or differential relays. Generally, this is accomplished by using a lockout relay (device 86) to disable closing of the reserve-source circuit breaker in the event that overcurrent relays initiate tripping of the normal-source circuit breaker.

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