Voltage Unbalance & Single-Phasing

Single-Phasing On Secondary Delta-Connected Motor, FLA = 10 Amps

Normal Condition

![Diagram showing normal condition](image)

Single-Phasing Condition

![Diagram showing single-phasing condition](image)

Assume the contacts on one phase are worn out resulting in an open circuit.

Delta-connected three-phase motor loaded to only 65% of its rated horsepower. Normal FLA = 10 amps. Overload (overcurrent) protection should be based upon the motor’s actual current draw for the underloaded situation for optimum protection. If load varies, overload protection is difficult to achieve. Temperature sensors, phase failure relays and current differential relays should be installed.

When a motor is single-phased, the current in the remaining two phases increases to 173% of normal current. Normally the overload relays will safely clear the motor from the power supply. However, should the overload relays or controller fail to do so, Low-Peak or Fusetron time-delay, dual-element fuses, properly sized to provide back-up overload protection, will clear the motor from its power supply.

If the overload relays were sized at 12 amps, based upon the motor nameplate FLA of 10 amps, they would not “see” the single-phasing. However, if they were sized at 8 amps (6.5A x 1.25 = 8.13 amps), they would “see” the single-phasing condition.

Single-Phasing on Transformer Primary – Typical Causes

1. Primary wire broken by:
   a. Storm – wind
   b. Ice – sleet – hail
   c. Lightning
   d. Vehicle or airplane striking pole or high-line
   e. Falling trees or tree limbs
   f. Construction mishaps
2. Primary wire burned off from short circuit created by birds or animals.
3. Defective contacts on primary breaker or switch – failure to make up on all poles.
4. Failure of 3-shot automatic recloser to make up on all 3 poles.
5. Open pole on 3-phase automatic voltage tap changer.
6. Open winding in one phase of transformer.
7. Primary fuse open.
Motor Protection

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Hazards of Primary Single-Phasing For A Three-Phase Motor

Probably the most damaging single-phase condition is when one phase of the primary side of WYE/DELTA or DELTA/WYE transformer is open. Usually these causes are not within the control of the user who purchases electrical power. When primary single-phasing occurs, unbalanced voltages appear on the motor circuit, causing excessive unbalanced currents. This was covered earlier in this bulletin. When primary single-phasing occurs, the motor current in one secondary phase increases to 230% of normal current. Normally, the overload relays will protect the motor. However, if for some reason the overload relays or controller fail to function, the Low-Peak and Fusetron time-delay, dual-element fuses properly sized to provide backup overload protection will clear the motor from the power supply.

Effect of Single-Phasing on Three-Phase Motors

The effects of single-phasing on three-phase motors varies with service conditions and motor thermal capacities. When single-phased, the motor temperature rise may not vary directly with the motor current. When single-phased, the motor temperature may increase at a rate greater than the increase in current. In some cases, protective devices which sense only current may not provide complete single-phasing protection. However, PRACTICAL experience has demonstrated that motor running overload devices properly sized and maintained can greatly reduce the problems of single-phasing for the majority of motor installations. In some instances, additional protective means may be necessary when a higher degree of single-phasing protection is required. Generally, smaller horsepower rated motors have more thermal capacity than larger horsepower rated motors and are more likely to be protected by conventional motor running overload devices.

Case Study

During the first week of January, 2005, an extended primary single phasing situation of over two hours occurred at the Cooper Bussmann facility in St. Louis, Missouri. While the utility would not divulge the root cause of the single-phasing incident, Cooper Bussmann was running over 100 motors in their St. Louis facility. Since the motors were adequately protected with a motor overload protective device or element in each phase (such as a starter with three heater elements/overload relay) and with three properly sized Fusetron or Low-Peak fuses for backup motor overload protection, all motors survived the single-phasing incident. Not a single motor replacement nor repair was needed and the facility was quickly returned to service after replacing fuses and resetting overload relays.

Summary of Suggestions to Protect Three-Phase Motors Against Single-Phasing

1. Per NEC® 430.37, three-phase motors must have an overload protective device in each phase. Use motor overload protection such as overload relays/heater elements in each phase of the motor. Prior to 1971, only two overload protective devices were required and motors were much more susceptible to motor burnout.
2. For fully loaded motors, size the heater elements or set the overload protection properly per the motor nameplate FLA.
3. If the motor is oversized for the application or not fully loaded, then determine the full load current via a clamp on amp meter and size the heaters or set the overload protection per the motor running current.
4. Electronic motor overload protective devices typically have provisions to signal the controller to open if the phase currents/voltages are significantly unbalanced.
5. Install phase voltage monitor devices that detect loss of phase or significant imbalances and signal the controller to open.
6. Periodically test overload protective devices using proper testing equipment and procedures to ensure the overload heaters/overload relays are properly calibrated.

With one or more of the above criteria, three-phase motors can be practically protected against overloads including single-phasing. Then the motor circuit branch circuit, short circuit, ground fault protection required per NEC® 430.52 can be achieved by many different types of current-limiting fuses including LPJ, SP, LP-CC, TCF, LPN-R, LPS-R, FRN-R, FRS-R, JJS, JNJ, SC and others. Many personnel size these fuses for short circuit protection only. However, some engineers and maintenance personnel want another level of protection and utilize the fuse types and sizing in (7) below.

7. In addition to the motor overload protection in the circuit, use three Fusetron dual-element, time-delay fuses (FRS-R/FRN-R) sized for backup motor overload protection. Low-Peak dual-element, time-delay fuses (LPS-RKL/PN-RK) can also be used, but in some cases, must be sized slightly greater than the FRS-R and FRN-R fuses. These fuses, sized properly, serve two purposes: (1) provide motor branch circuit, short circuit and ground fault protection (NEC 430.52) and (2) provide motor running back-up overload protection. For further details, refer to the Motor Circuit Protection section or contact Cooper Bussmann Application Engineering.