Transformer Protection

Course No: E01-006
Credit: 1 PDH

Andre LeBleu, P.E.

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.com

Transformer Protection

Two Winding Three Phase Transformer

This transformer protection document describes the means to provide overcurrent protection of two winding three phase transformers. Typical applications described in this document are for industrial sites, such as chemical plants and oil refineries, where transformer primary voltage levels range from 2.4kV to 15kV level (2400V, 4160V, 13800V and 14400V).

Transformers are an extremely critical part of any electrical system. Since transformers are also usually very reliable, failures are usually unplanned and can result in system downtime that may exceed typical expectations. Transformer overcurrent failure in many cases cannot be seen and the intent of this document is to inform on this matter so concerned personnel can plan accordingly.

For a transformer, an overcurrent situation can be either or both of two situations:

- Current loading a transformer above its rated capacity. (This situation is described as overloading.)

- A short circuit occurs in the electrical system causing an extremely high amount of current through or into the transformer.

Either of these situations can result in damaging a transformer. The first situation will usually require a long time to produce noticeable damage. The second situation or combination of both usually produces immediate results.

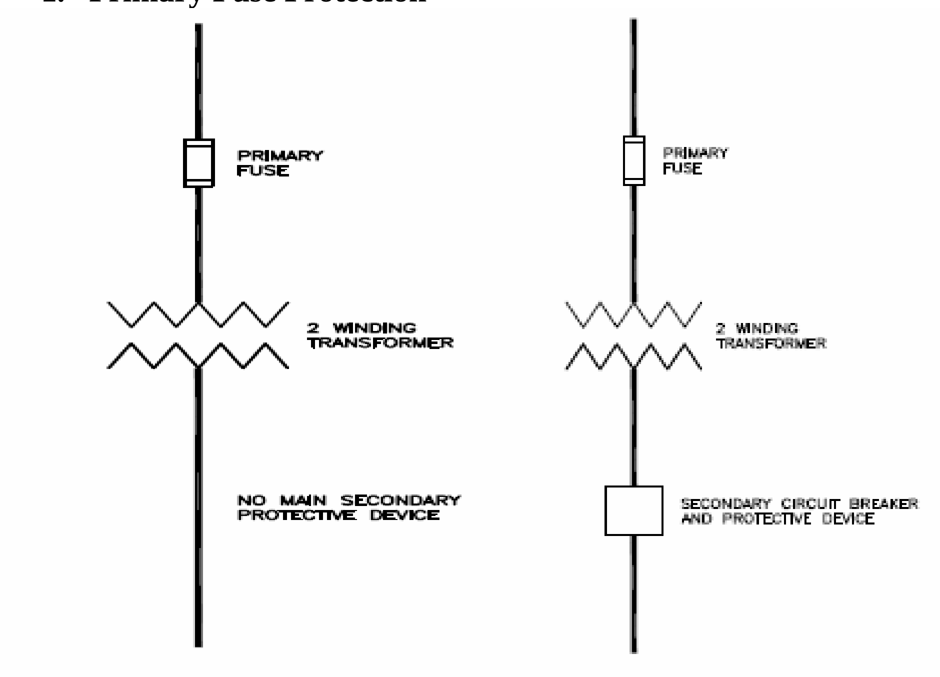
The failure of a transformer can produce the following results:

- Transformer electrical system is turned off due to failed electrical component (transformer).
- If the overcurrent situation ruptures the tank, possible environmental contamination may occur if the insulating material leaks onto the ground.
- If the transformer has to be replaced or repaired, possibly days or weeks of downtime for secondary electrical system may occur until the transformer can be repaired/replaced and reinstalled.
- Personnel safety issues may result.

The best remedy is suitable overcurrent protection to prevent overloading and to quickly isolate the transformer from short circuits on the electrical system. With implementing an overcurrent protection system it is hoped that if a failure does occur, it will be minimal allowing quicker return to service.

Four (4) typical methods of transformer overcurrent protection are described as below:

1. Primary Fuse Protection



Examples of Primary Fuse Transformer Protection

The simplest form of protection is a fuse installed on the primary of the transformer. This installation has the following attributes:

- Installation can be custom enclosure with fused switches to a cutout type installation on a pole depending on system requirements.

- Sizing of fuse can typically be determined in accordance with the National Electrical Code requirements for transformer protection. This same section also provides information regarding secondary protection requirements.

Pro:

- Simplest installation.

- Usually least costly initial installation.

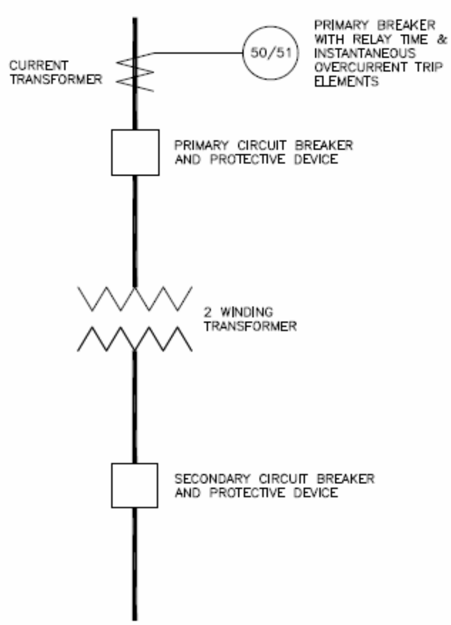
Con:

- In the event that fuses blow, new replacement fuses are required.

- Requires coordinating primary fuse protection with upstream and secondary protective devices.

- These installations can be least desirable for arc flash remediation. Prior to using this type of installation, arc flash energy should be calculated to determine if this installation will provide suitable arc flash protection and full utilization of the required transformer capacity.

2. Primary Circuit Breaker with 50/51 Relay Protection



Example of Primary Circuit Breaker with 50/51Relay Protection

This transformer protection is a primary circuit breaker with time overcurrent trip element (51) and instantaneous overcurrent trip element (50). This installation has the following attributes:

- Requires switchgear for primary circuit breaker, protective relay devices for the 50/51 trip elements, current transformers, and necessary auxiliary equipment.

- Current transformers:
    - Sized to meet National Electrical Code requirements for transformer protection.
    - Allow full utilization of transformer capacity.
    - Rated for available fault current situation to avoid saturation.

- Protective relay devices need to be set to meet the National Electrical Code requirements for transformer protection, allow full utilization of transformer capacity, and protect against fault within transformer.
    - The 51 function is used to protect against overload of the transformer.
    - The 50 function is used to protect against fault within the transformer. (This setting needs to be coordinated so it does not trip faster than downstream protection.)
        - It is not the intention for this protective device to trip for faults exterior to the transformer beyond the next set of downstream protective devices unless these devices have failed.

Pro:

- Much better protection than previously described due to protection selectivity.

- Trip devices are resettable and can be reused after fault is repaired usually without any changes.

- 50/51 devices provide capability to provide more effective arc flash protection.

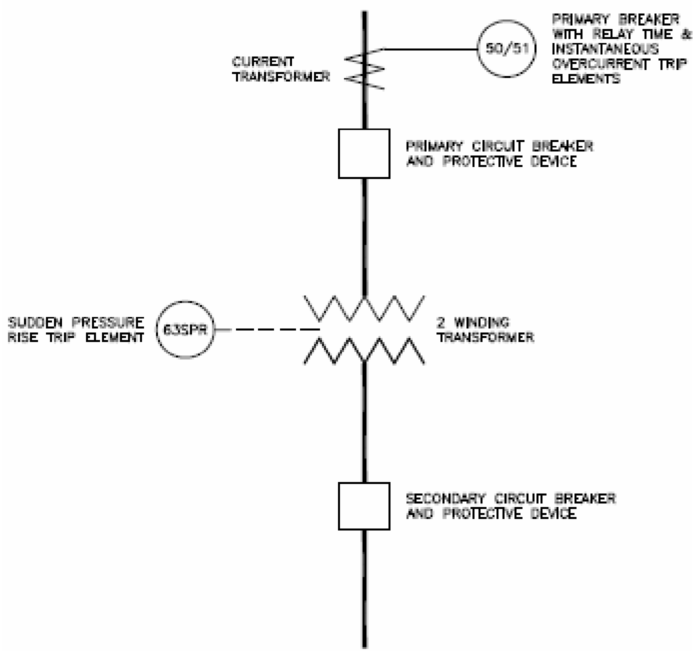
Con:

- Requires coordination study to develop best settings.

- Much more expensive than previously described installation.

- Due to the resettable nature of protection, personnel have to be trained to find and repair fault instead of just resetting and closing the circuit breaker.

3. Primary Circuit Breaker with 50/51 Relay Protection and 63SPR Protection



Example of Primary Circuit Breaker with 50/51Relay Protection and 63SPR Protection

This transformer protection is a primary circuit breaker with time overcurrent trip element (51), instantaneous overcurrent trip element (50), and sudden pressure rise trip element (63SPR). This installation has the following attributes:

- Requires a switchgear for the primary circuit breaker, protective relay devices for the 50/51 trip elements, current transformers and necessary auxiliary equipment.

- Current transformers:

  - Sized to meet the National Electrical Code requirements for transformer protection.
  - Allow full utilization of transformer capacity.
  - Rated for available fault current situation to avoid saturation.

- The 63SPR relay is mounted on the transformer and monitors pressure change within the transformer. If sufficient pressure rise is measured by the relay, a trip will be enabled. There are 2 basic methods for performing the trip:

  - The 63SPR relay utilizes a trip and seal in the device that trips the primary circuit breaker and seals in the trip to prevent reclosing the circuit breaker until the seal in device is reset. This is to ensure that technicians will determine why the trip occurred and repair any fault damage before reclosing the circuit breaker.
  - The 63SPR relay utilizes a trip which trips an 86 lock-out relay mounted on the switchgear containing the circuit breaker. This trip system works

as follows: The 63SPR relay trips the 86 lock-out relay which trips the primary circuit breaker and locks out the close circuit to prevent reclosing the circuit breaker until the 86 lock-out relay is reset. This is to ensure that technicians will determine why the trip occurred and repair any fault damage before reclosing the circuit breaker.

- Protective relay devices need to be set to meet the National Electrical Code requirements for transformer protection, allow full utilization of transformer capacity, and to protect against fault within the transformer.

    - The 51 function is used to protect against overload of the transformer.
    - The 50 function is used to protect against fault within the transformer. (This setting needs to be coordinated so it does not trip faster than downstream protection.)
        - It is not the intention for this protective device to trip for faults exterior to the transformer beyond the next set of downstream protective devices unless these devices have failed.

Pro:

- 63SPR relay provides increased protection because it is intended to sense internal transformer problems and take transformer offline before fault situation occurs.

- Better protection than previous schemes.

- Trip devices are resettable and can be reused after fault is repaired usually without any changes.

- 50/51 devices provide capability to provide more effective arc flash protection.

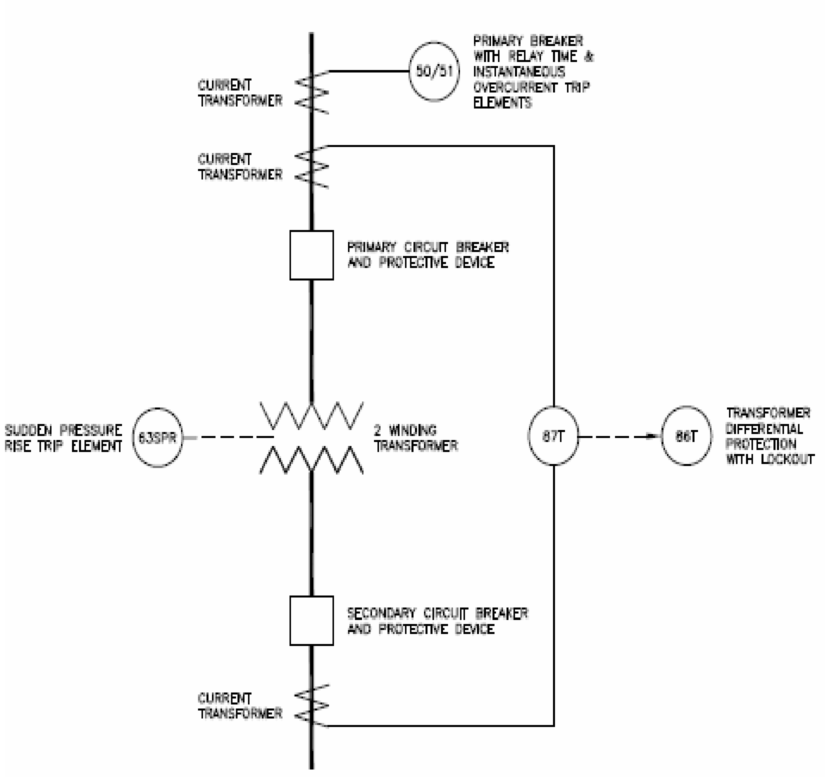
Con:

- Requires coordination study to develop best settings for 50/51 devices.

- More expensive than previously described installation and transformer has to have capability to mount 63SPR device.

- Due to resettable nature of protection, personnel have to be trained to find and repair fault instead of just resetting and closing circuit breaker.

4. **Primary and Secondary Circuit Breakers with 50/51 Relay Protection, 63SPR Protection, and 87T Protection**



Example of Primary and Secondary Circuit Breaker with 50/51Relay Protection, 63SPR Protection, and 87T Protection

The next upgrade in transformer protection is a circuit breaker with time overcurrent trip element (51), instantaneous overcurrent trip element (50), sudden pressure rise trip element (63SPR). and transformer differential trip element (87T). This installation has the following attributes:

- Requires a switchgear for the primary circuit breaker, protective relay devices for the 50/51 and 87T trip elements, current transformers and necessary auxiliary equipment.

- Requires a switchgear for the secondary circuit breaker, current transformers, and necessary auxiliary equipment.

- Current transformers:
  - Sized to meet the National Electrical Code requirements for transformer protection.
  - Allow full utilization of transformer capacity.
  - Rated for available fault current situation to avoid saturation.

- The 63SPR relay is mounted on the transformer and monitors pressure change within the transformer. If sufficient pressure rise is measured by the relay a trip will be enabled. For this type of installation the trip is typically performed as follows:

    - The 63SPR relay utilizes a trip which trips an 86 lock-out relay mounted on the switchgear containing the primary circuit breaker. This trip system works in this case as follows: The 63SPR relay trips the 86 lock-out relay which trips the primary and secondary circuit breakers and locks out the close circuits to prevent reclosing the circuit breakers until the 86 lock-out relay is reset. This is to ensure that technicians will determine why the trip occurred and repair any fault damage before reclosing the circuit breaker.

- Protective overcurrent relay devices need to be set to meet the National Electrical Code requirements for transformer protection, allow full utilization of transformer capacity, and to protect against fault within the transformer.

    - The 51 function is used to protect against overload of the transformer.
    - The 50 function is used to protect against fault within the transformer. (This setting needs to be coordinated so it does not trip faster than downstream protection.)
        - It is not the intention for this protective device to trip for faults exterior to the transformer beyond the next set of downstream protective devices unless these devices have failed.

- The 87T relay is mounted on the switchgear and monitors incoming and outgoing current. Two sets of current transformers are required. The best application is to have the current transformer sets mounted opposite the transformer side of the primary and secondary circuit breakers.

    - The 87T relay is a transformer differential type relay. It measures the current entering and leaving the transformer with the primary and secondary current transformers with an error allowance. If the difference meets the relay trip criteria, it instantaneously trips. This type of relay protection is faster than the 51 protection, and if current transformers are mounted as stated above, this can reduce arc flash requirements on the secondary circuit breaker.
    - The 87T relay utilizes a trip which trips an 86 lock-out relay mounted on the switchgear containing the primary circuit breaker. This trip system works as follows: The 87T relay trips the 86 lock-out relay which trips the primary and secondary circuit breakers and lock out the close circuits to prevent reclosing the circuit breakers until the 86 lock-out relay is reset. This is to ensure that technicians will determine why the trip occurred and repair any fault damage before reclosing the circuit breakers.

Pro:

- 63SPR relay provides increased protection because it is intended to sense internal transformer pressure rise and take transformer offline before fault situation occurs.

- Better protection than previous scheme.

- Trip devices are resettable and can be reused after fault is repaired usually without any changes.

- 50/51 devices provide capability for more effective arc flash protection.

- 87T device provides instantaneous tripping for fault within its protective zone.

- 87T device provides greatest capability to improve arc flash conditions if both primary and secondary circuit breakers are within current transformer zone.

Con:

- Requires coordination study to develop best settings for 50/51 elements.

- More expensive than previously described installations due to added equipment.

- Due to the resettable nature of protection, personnel have to be trained to find and repair fault instead of just resetting and closing the circuit breaker.

Experience Observations

Typical observations of installations:

- (The below statements assume secondary protection is provided that meets or exceeds protection required by the National Electrical Code.)

- For typical commercial applications and some light industrial applications the typical installation is pad mounted transformer provided with fused tap from local utility distribution wiring. This case is the primary fuse protection described above. Highly recommend determining arc flash energy levels and working with the local utility and or implementing safety standard as required to ensure safe installation and operation of electrical equipment. This may require:

    - Lowering the primary fuse rating which in extreme cases may affect full utilization of transformer capacity and/or developing boundary area and safe electrical work practices.

- Typical industrial applications for their normal applications will be a pad mounted or substation type transformer with a primary circuit breaker with 50/51 relay protection as described above. Highly recommend determining arc flash energy levels and implementing a safety standard as required to ensure safe installation and operation of electrical equipment. This may require:

  - Optimizing protective device settings and/or developing boundary area and safe electrical work practices.

- Typical industrial applications for their normal critical applications will be substation type transformer with a primary circuit breaker with 50/51 Relay protection and 63SPR protection as described above. Highly recommend determining arc flash energy levels and implementing a safety standard as required to ensure safe installation and operation of electrical equipment. This may require:

  - Optimizing protective device settings and/or developing boundary area and safe electrical work practices.

- Typical industrial applications for their critical applications will be substation type transformer with Primary and Secondary Circuit Breakers with 50/51 Relay Protection, 63SPR Protection, and 87T Protection as described above. Highly recommend determining arc flash energy levels and implementing a safety standard as required to ensure safe installation and operation of electrical equipment. This may require:

  - Optimizing protective device settings and/or developing boundary area and safe electrical work practices.

- Personnel training

  - With the installation of any of these protective schemes, the site technical operators and maintenance staff have to be trained to ensure that repair and/or replacement of faulted equipment occurs before reenergizing the tripped device(s).
  - (Author's note – I have been informed of multiple cases where transformer protective relaying has tripped and because there was no visible damage the transformers were returned to service usually with adverse effects.)

- For 87T electromechanical relays in most cases the current transformers have to be connected specifically based on the transformer winding. For example see below:

  - Delta transformer winding current transformers need to be connected in wye configuration.
  - Wye transformer winding current transformers need to be connected in delta configuration.

  - Required engineering personnel need to ensure protective relay requirements are met.

Conclusion

This document describes different levels of transformer protection. It is highly recommended that qualified personnel develop the following criteria for transformer protection:

- Preferred levels of protection basis.

- Required action after protective devices trip.

- Plan for an electrical system in the event of transformer failure.

(Note: This document is for information only and not an engineered document. This document cannot be used as a final engineered product. This document does not provide any warranties or guarantees relating to its contents, applications, or results.)