Protective Grounding

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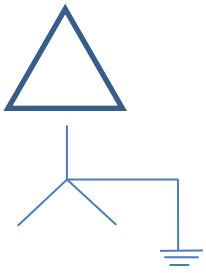
PROTECTIVE GROUNDING

Introduction

Protective grounding is the means to provide safety, reliability, and maintainability of electrical systems comprised of majority three phase loads. Typical applications described in this course are industrial sites such as chemical plants and oil refineries. Voltage levels are 15kV to 480V level (14400kV, 13800kV, 4160kV, 2400V, 480V). These are typical level of voltages for this application.

Transformer with Reactor Grounding System

The main requirement of electrical systems for industrial sites is maximum uptime. Typical unscheduled electrical system shutdowns are caused by single line to ground faults. This course discusses transformer accessory applications to remedy single line to ground fault effect on electrical system operation.



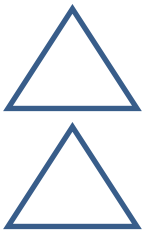
Graphic of Delta-Wye Solidly Grounded Transformer Neutral

Most electrical systems use Delta-Wye solidly grounded transformers. This type system utilizes a solidly grounded neutral. In the event of a single line to ground fault there is a direct phase connection to ground completing the circuit with ground as the load, and minor canceling effect from the other phases.

Single line to ground fault is a short circuit of one of the three phases powering a load. In other words, one of the three conductors powering a load has an insulation failure connecting the conductor to ground (and transformer neutral). The results can be catastrophic based on the system parameters. This will provide negative impact on safety, reliability and maintainability with the most important point that this is a safety issue that can result in a hazard to humans.

Below are described alternatives to Delta-Wye solidly grounded transformer system with the purpose of providing greater safety, reliability and maintainability for electrical systems in regards to single line to ground fault:

Delta-Delta Configured Transformers



Graphic of Delta-Delta Transformer

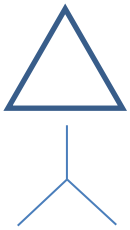
The basis of this system is that there is no neutral to provide point for single line to ground fault current return allowing the electrical system to operate without interruption. The single line ground faults are monitored using a low voltage circuit to ground with a light from each phase. If a phase light goes out, there is a single line to ground fault on that phase. The problem with the system is that there is no way to find the single line to ground fault without turning off the load. If the system is large (for example multiple MCC's with multiple motors and various loads) and max uptime is required, the fault may never be found during normal operation because of system operational requirements. If an existing single line to ground fault is on the system and a second single line to ground fault occurs, catastrophic damage will occur because now the system has a return path back to the transformer system.

This type of transformer may be applied at all voltage levels.

Pro – Allows one single line to ground fault without system interruption.

Con – Difficult to find first single line to ground fault.

Delta-Wye Ungrounded Transformers



Graphic of Delta-Wye Ungrounded Transformer Neutral

The basis of this system is that the neutral is not grounded, thereby not providing a point for single line to ground fault current return allowing the electrical system to operate without interruption. The problem with this system is that there is no way to find the first single line to ground fault. If an existing single line to ground fault is on the system and a second single line to ground fault occurs, catastrophic damage will occur because now the system has a return path back to the transformer neutral.

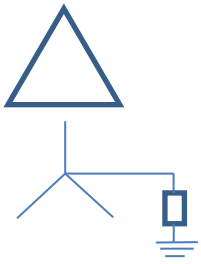
Additionally imbalances on the system will be reflected back on to electrical system with unpredictable results. This will result in lower level of safety, reliability and maintainability.

This type of transformer may be applied at all voltage levels.

Pro – Allows one single line to ground fault without system interruption.

Con – Difficult to find or notice first single line to ground fault. Also system imbalance causes additional problems that can affect system reliability. (This system is not recommended for use due to stated issues.)

Delta-Wye High Resistance Grounded Transformers



Graphic of Delta-Wye Resistance Grounded Transformer Neutral

High resistance grounding is the means of installing a resistor between the transformer neutral and system ground to limit single line to ground faults to lower value typically less than 10 amps for an extended period of time. Typical systems can also provide:

- Indication lights to show the existence of a single line to ground fault.

- Contacts that can be connected to reporting systems so that site personnel can be alerted about the single line to ground fault.

- Pulsing circuit that adds and removes resistance to circuit in a pulsing fashion so that site personnel using an ammeter large enough to fit around all three phases of a circuit can find single line to ground fault without turning off load.

The typical application for single line to ground fault detection is single phase level voltage on the transformer neutral. This voltage setting can be falsely tripped if high system voltage imbalance or significant voltage harmonics exist.

This type of transformer system may be applied at 600V or lower voltage levels. While, high resistance grounding is available for higher voltage systems, there are concerns as follows:

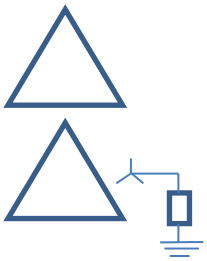
- Typical grounding cable is 600V insulated introducing a safety issue into the grounding system for applications with voltages greater than 600V.

- Typically wiring with above 600V cable insulation is rated for the 3 phase voltage level. For example a cable with 2,400 voltage level stated on cable jacket is rated 1,386 volts single phase. A transformer with secondary voltage of 2,400V can have a nominal neutral voltage of 1,386V. The nominal neutral voltage can be the same or higher than the cable rated voltage due to electrical system requirements. This cable needs to be sized and insulated to meet maximum voltage and duration of ground fault requirements.

Pro – Allows one single line to ground fault without system interruption with the ability to locate single line to ground fault with minimum system interruption.

Con – Catastrophic damage can result if more than one single line to ground fault occurs. System imbalance and voltage harmonics can cause false indication of single line to ground fault.

Delta-Delta High Resistance Grounded Transformers



Graphic of Delta-Delta Resistance Grounded Transformer Neutral with Auxiliary Transformer

High resistance grounding is the means of installing a resistor between the transformer neutral and system ground to limit single line to ground faults to lower value typically less than 10 amps for an extended period of time. Auxiliary transformers are required to create wye configuration. Typical systems can also provide:

- Indication lights to show the existence of a single line to ground fault.
- Contacts that can be connected to reporting systems so that site personnel can be alerted about the single line to ground fault.
- Pulsing circuit that adds and removes resistance to a circuit in a pulsing fashion so that site personnel using an ammeter large enough to fit around all three phases of a circuit can find single line to ground fault without turning off the load.

The typical application for single line to ground fault detection is single phase level voltage on the transformer neutral. This voltage setting can be falsely tripped if high system voltage imbalance or significant voltage harmonics exist.

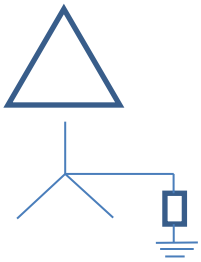
This type of transformer system may be applied at 600V or lower voltage levels. While high resistance grounding is available for higher voltage systems, there are concerns as follows:

- Typical grounding cable is 600V insulated introducing a safety issue into the grounding system for applications with voltages greater than 600V.
- Typically wiring with above 600V cable insulation is rated for the 3 phase voltage level. For example a cable with 2,400 voltage level stated on cable jacket is rated 1,386 volts single phase. A transformer with secondary voltage of 2,400V can have a nominal neutral voltage of 1,386V. The nominal neutral voltage can be the same or higher than the cable rated voltage due to electrical system requirements. This cable needs to be sized and insulated to meet maximum voltage and duration of ground fault requirements.

Pro – Allows one single line to ground fault without system interruption with the ability to locate single line to ground fault with minimum system interruption.

Con – Catastrophic damage can result if more than one single line to ground fault occurs. System inbalance and harmonics can cause false indication of single line to ground fault. It requires additional auxiliary transformers to create wye configuration.

Delta-Wye Low Resistance Grounded Transformers



Graphic of Delta-Wye Resistance Grounded Transformer Neutral

Low resistance grounding is the means of installing a resistor between the transformer neutral and system ground to limit single line to ground faults to low value typically multitudes less than solidly grounded neutral in the event of single line to ground fault. Typical systems also provide:

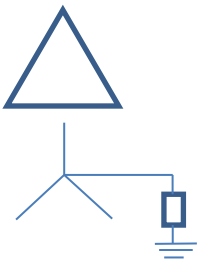
- 10 second rated resistor system that allows single line to ground relaying to be set much more sensitive than phase protection relaying, thereby getting fault off line quicker.

This type of transformer system may be applied at above 600V level systems.

Pro – Reduces single line to ground fault current to lower value restricting damage and allows getting fault off line quicker.

Con – Requires high voltage equipment with spacing as required.

Delta-Wye Low Impedance Reactor Grounded Transformers



Graphic of Delta-Wye Reactor Grounded Transformer Neutral

Reactance grounding is the means of installing a reactor between the transformer neutral and system ground to limit single line to ground faults to low value typically multitudes less than solidly grounded neutral in the event of single line to ground fault. Typical systems also provide:

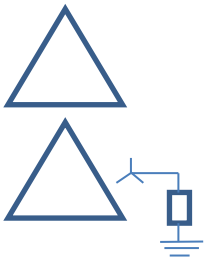
- 10 second rated reactor system that allows single line to ground relaying to be set much more sensitive than phase protection relaying, thereby getting fault off line quicker.

This type of transformer system may be applied at above 600V level systems.

Pro – Reduces single line to ground fault current to lower value restricting damage and allows getting fault off line quicker.

Con – Requires high voltage equipment with spacing as required. This application is rarely used for stated facilities.

Delta-Delta Low Resistance Grounded Transformers



Graphic of Delta-Delta Resistance Grounded Transformer Neutral With Auxiliary Transformer

Low resistance grounding is the means of installing a resistor between the transformer neutral and system ground to limit single line to ground faults to low value typically multitudes less than solidly grounded neutral in the event of single line to ground fault. Typical systems also provide:

- Auxiliary transformers are required to create wye configuration. Auxiliary transformers are required to be rated for resistor ampacity. This is typically a transformer specifically intended for this application.

- 10 second rated resistor system that allows single line to ground relaying to be set much more sensitive than phase protection relaying, thereby getting fault off line quicker.

This type of transformer may be applied at above 600V level systems.

Pro – Reduces single line to ground fault current to lower value restricting damage and allows getting fault off line quicker.

Con – Requires high voltage equipment and transformer with spacing as required.

Conclusion

The current most popular methods of protective grounding for industrial systems are:

- High resistance grounding applied on Delta-Wye transformers with 600V or lower secondary systems. This allows continued operation of electrical system without outage and the ability to locate faults with minimum outage.

- Low resistance grounding applied on Delta-Wye transformers with higher than 600V secondary systems. This allows safer operation of electrical systems with quicker trip time and the ability to minimize fault energy.

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