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TRANSFORMER SWITCHING & PROTECTION:

FOUR CONSIDERATIONS TO ENSURE RELIABLE, LONG-LIFE PERFORMANCE

- ***Southern States LLC***

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For utilities, proper protection against high voltage transient overvoltages and overloads is critical to ensure maximum life of their power transformers. Failure to do so can result in significant financial impact to the utility in terms of damaged equipment and loss of revenue due to extended customer outages.

Utilities are facing an aging infrastructure along with rapid commercial and residential growth. This often results in the replacement of existing protective equipment to meet increased fault level requirements, as well as the addition of new equipment to meet system growth. A cost-effective primary-side transformer protection device can offer value, providing reliable, three-phase interruption of fault currents.

Selection of Primary Side Transformer Protection

The selection of a primary-side transformer protective device calls for a thorough understanding of what duties the device must perform, as it should offer reliable and cost-effective performance over its expected lifetime of 20-30 years. Key factors to consider when selecting the protective device include reliability, footprint and interruption of transformer limited faults which account for 90% of the faults that the device will interrupt.

Power Fuses

For small and medium size transformers (typically < 10 MVA), power fuses may serve as the primary overcurrent protective device. Fuses are historically the least expensive, both in purchase and installation costs, and simplest form of an electrical protection device. In this application, the fuse can be sized to provide overcurrent protection for faults that occur between the fuse and the nearest secondary protective device.

Power fuses can also serve as backup protection for the secondary protective device as well. However, their application may be limited as they are a one-time device (fuse must be replaced after each interruption), are single phase by design, and have limited fault current interruption ratings. Additionally, they are sometimes difficult to coordinate with both upstream and downstream devices. As fault levels grow, this coordination becomes more difficult; the the fuse interrupting capacity may not be adequate, and the need for three-phase operation increases. This has led many utilities to pursue use of other traditional transformer protective devices including circuit breakers and circuit switchers.

Circuit Breakers

A circuit breaker is an electric switch designed to protect an electrical circuit and/or equipment from damage caused by excess current from an overload or short circuit. Its basic function is to convert from being an ideal conductor to an ideal insulator, in the shortest amount of time possible, by interrupting current flow after a fault is detected. Circuit breakers are a popular solution for protection of power transformers, which account for approximately 25% of their applications. Their general-purpose design makes them ideal for complex bus scheme switching and protection as well as transmission line protection. Many of these applications require the ability to quickly (2-3 cycles) interrupt high current faults in excess of 40 kA sym. For bus and line protection, the integration of CTs to the circuit breaker bushings (for dead tank designs) helps minimize installation and equipment costs.

While this general-purpose design has many benefits, it is not always the best solution for a specific application. This holds true for transformer protection applications where fast transient recovery voltages (TRVs) can take place during interruption of transformer limited faults. Transformer limited faults originate on the secondary side of the transformer but are interrupted by the primary side protective device. ANSI/IEEE circuit breaker standards do not require assurance testing to this phenomenon. While there is a published standard for circuit breakers (C37.06.1) that encourages additional testing for fault interruption during fast TRVs, most circuit breaker manufacturers do not run these costly tests unless specifically requested.

Circuit Switchers

Circuit switchers are a third option utilities can consider for transformer switching and protection. Unlike circuit breakers, circuit switchers are designed and tested specifically for high voltage, transformer protection and switching. Circuit switchers are tested to ANSI C37.016, which includes testing for fast TRV rise times that are typical during interruption of transformer limited faults.

Since most interrupted faults will be transformer limited faults, circuit switchers will typically utilize the transformer's bushing mounted, current transformers for current sensing. This leads to a reduction in footprint and cost when compared to a traditional circuit breaker. Circuit switchers are available with up to a 40 kA primary-fault interruption and 3 cycle interruption but can also be found with lower fault interrupting ratings and slower interrupting times (5-6 cycle). This is often sufficient for the application. Circuit switchers can also include accessories such as an integral disconnect switch, integral ground switch, current sensors or traditional current transformers.

Interrupter Design

Selecting a primary side transformer protection device that can be relied on to interrupt transformer limited faults is important, as most faults interrupted by the primary protective device are faults that originate on the secondary side of the transformer.

The typical circuit breaker is designed to interrupt and clear an overcurrent fault quickly. Many breaker designs utilize an auxiliary contact that helps increase arc energy (arc assisted design), resulting in increased gas pressure that can quickly interrupt the arc. While this is helpful for interrupting overcurrents more quickly, it can present challenges when fast TRV faults must be interrupted.

In contrast, circuit switcher interrupters are required, by standard, to interrupt these fast transient TRV transformer limited faults. This requirement will typically make it difficult to provide the higher interrupting levels and extreme interrupting speeds that are available in some circuit breakers.

Space Limitations & Adaptability

For utilities, where substation space limitations exist or where land costs are prohibitively expensive, construction and/or maintenance of their new and existing high voltage substations can pose significant challenges. When selecting a protection device, these utilities must maximize the available space they have and consider those devices which are adaptable to their system and take up less footprint.

Circuit switchers offer some advantages over circuit breakers. They have a smaller footprint than a circuit breaker and can often be mounted on existing structures, replacing older protective devices that may have lower ratings. They can also be designed with an integrated disconnect switch, arrestors, ground switches and current monitoring devices that allow for greater customization to address the unique needs of the utility.

In addition to substation applications, horizontal circuit switchers are also ideal in high voltage mobile trailer applications, where their weight and size, versus a general-purpose circuit breaker, offer substantial value to the user. When deployed, they can be supplied on a racking mechanism that provides the required phase-to-phase spacing required for safe operation.

SF_6 Gas Emissions

With growing concerns on our planet's greenhouse gas emissions, many utilities are looking to eliminate or reduce their contribution to SF6 emissions. For systems with high fault potential, where power fuses are not appropriate, the use of SF6 gas is still the primary arc extinguishing medium used in transformer protective devices.

It is not unusual for a circuit breaker to require 80 lbs. of SF6 gas. Compare this to less than 20 lbs. of SF6 required for circuit switchers, and you are looking at a significant reduction in SF6 used as well as consequences if a leak occurs. Vacuum circuit breakers are now widely available for some applications at 72 kV and below but have limitations in some applications due to maximum fault interrupting capabilities and the tendency to current chop in certain applications. There is significant research toward alternative gases, but to date SF6 remains the best alternative when considering performance and cost.

Conclusion

When selecting a primary protection device for your transformer, it's important to make several considerations, including high TRV transformer limited fault interrupting capability, interruption methodology, design adaptability, and the amount of SF6 gas utilized. The appropriate choice should seek a cost-effective solution that does not sacrifice reliability.

Horizontal and vertical circuit switchers are an optimal choice when utilities want a reliable, purpose-specific device for transformer protection that can adhere to these considerations. To learn more about Southern States' line of circuit switcher products, download their brochure here.

Southern States
The Quality Name in High Voltage Switching

30 Georgia Avenue Hampton, GA 30228
P 770-946-4562 F 770-946-8106
sales@southernstatesLLC.com
www.southernstatesLLC.com

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