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Reactors vs. Current Limiting Protectors:
A comparative analysis for Electrical System Protection

Reactors and current limiting protectors are critical components in electrical power systems; each serving to mitigate fault currents and protect equipment. This paper provides a comparative analysis of their operational principles, advantages, disadvantages and cost.

Electrical power systems require robust protection mechanisms to prevent damage from fault currents, which can arise from short circuits or overloads. Two common devices for fault current mitigation are reactors and current-limiting protectors. Reactors limit fault currents by introducing impedance, while current-limiting protectors interrupt fault currents via pyrotechnics and a melting fuse element. Each solution has its own application: reactors offer flexibility in continuous operation, while current-limiting protectors excel in rapid fault interruption.

The rise of smart and decentralized grids, increased urbanization, broader electrification across industries, and the growth of data centers — along with a global surge in air conditioning use — are contributing to record-breaking power demand. This surge in power flow leads to higher and potentially dangerous fault currents within the system.

What's at stake in this higher-risk power landscape? Service, equipment, the environment, and, most importantly, human lives. But cost efficiency is critical, too. Traditional reactors have been a popular choice for fault protection due to high ratings and lower initial price. **However, a closer look at capabilities and cost of ownership shows that an investment in advanced current limiting protectors delivers more long-term cost efficiency.**

DID YOU KNOW?

The industry is rapidly shifting towards more complex and distributed electrical systems. According to a recent study, **decentralized power generation** and **smart grid development** are identified as the most significant trends impacting current limiting protector market growth.

Source: Current Limiting Reactors Report,
Prepared for G&W Electric by WTWH Media LLC.

Operational Principles: How Protection and Efficiency Are Evolving

Circuit breakers – protecting, not limiting

Circuit breakers operate by interrupting the electrical current when it detects an abnormality, such as an excessive flow of current or a fault in the system. They have largely replaced one-time-use fuses because of their ability to be re-used and reset, which reduces maintenance costs and downtime. They can also be fine-tuned to trip at specific current levels.

However, circuit breakers have limitations, particularly in today's electric power landscape:

- Interrupts the flow of energy, but does not limit it
- Higher fault current let-through
- Low speed: Requires 3-5 cycles to clear the fault
- Long lead times on higher ratings

Reactors – limiting magnitude

Reactors are the traditional protection that improve on fuses and circuit breakers by reducing the magnitude of fault current, providing better overall protection relative to the circuit breaker. Typically, air-core or iron-core, they limit fault currents by introducing inductive reactance in series with the circuit. Reactors are rated based on their impedance and continuous current-carrying capability.

Reactors are widely available, offer high ratings and possibly a lower initial price, but the key disadvantages cut into cost efficiency:

- Low power efficiency adds to system losses
- Poor power quality through voltage sags
- Size: large and bulky; less suitable for more cost-efficient retrofits
- Longer lead time

CLiP® Current Limiting Protectors– limiting magnitude and duration

G&W Electric's CLiP current limiting protector combines the benefits of circuit breakers and fuses and is engineered to directly limit fault currents by introducing a high-impedance path during fault conditions. They are an electronically sensed and triggered, commutating form of protection using a copper busbar path to carry continuous current.

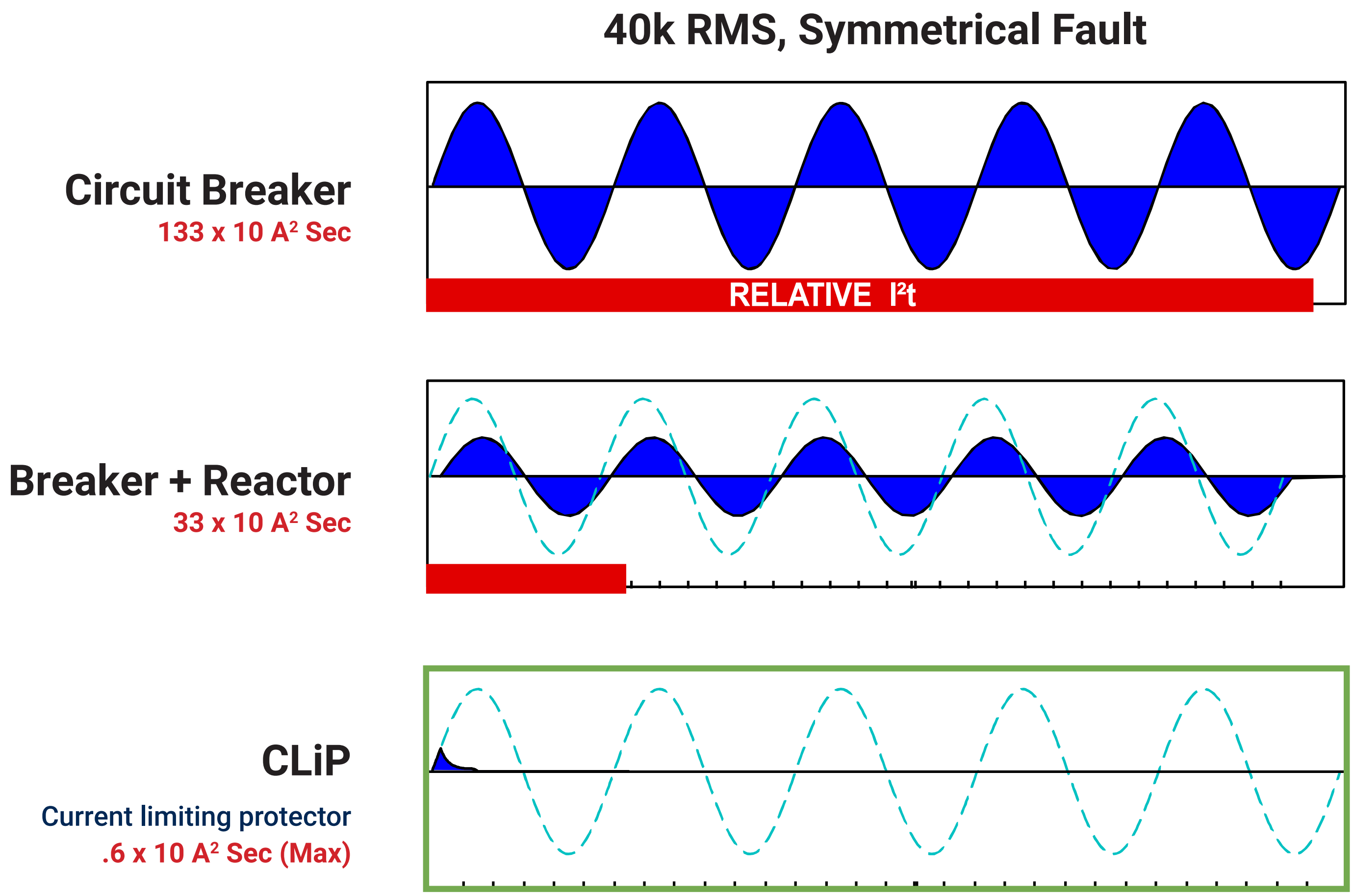
Once a fault is detected, a signal is sent to the CLiP current limiting protector's interrupter to trip and isolate the fault. The fault clears within ¼-½ electrical cycle. Unlike reactors, CLiP current limiting protectors quickly reduce the total duration and the energy released by a fault.

And when it comes to the particular risk of arc flashes, CLiP current limiting protectors are superior to other forms of protection because they quickly eliminate energy rather than channeling it.

CLiP current limiting protectors offer a more efficient total cost of ownership:

- Limits magnitude and duration of fault
- No energy losses
- Clears fault in ¼-½ of an electrical cycle
- Size: small, compact size; indoor or outdoor use
- Maintenance: lower cost and less frequent; no fuse aging
- Continuous current rating up to 5,000A
- High product longevity
- Retrofit or upgrade a reactor system with a bypass switch

Relative let through energy in a fault event



Calculating Cost Efficiency and ROI

CLiP Current Limiting Protectors vs. Current-Limiting Reactors

Reactors usually have a lower upfront cost when compared to the CLiP current limiting protector in the same current and voltage ratings. But reactors incur continuous power losses due to their resistance. The two examples below compare total cost of ownership of reactor vs the CLiP current limiting protector.

Case Study: Reducing fault current efficiently

A chemical plant needs to reduce fault current on their distribution gear and is considering either installing a current-limiting reactor or CLiP current limiting protector to mitigate fault current. The reactor has a capacity of 5000kVAR with a power efficiency of 98%. It is expected to operate at 70% capacity while active and remain active 90% of the year.

In comparison, CLiP current limiting protector has no power losses. Furthermore, the local utility charges the plant 0.087 $/kWh, and the power factor is 0.95. They have received a CLiP current limiting protector quote for an initial cost of $160,000 and a reactor quote for an initial cost of $75,000. How many years until the CLiP current limiting protector becomes more cost effective relative to the reactor? How much would the chemical plant save by using a CLiP current limiting protector instead of a reactor over a duration of 20 years?

Annual cost of reactor losses - Calculation method for determining annual cost (losses) of a reactor:

$$m = \left(S * PF * \frac{n_{load}}{100}\right) * \left(1 - \frac{n_{reactor}}{100}\right) * \left(t_{yr} * \frac{n_{active}}{100}\right) * Z$$

$$S = kVA\ rating\ of\ reactor$$
$$PF = \text{Power factor}$$
$$n_{load} = percentage\ of\ reactor\ capacity\ used\ while\ active\ over\ a\ year$$
$$n_{reactor} = percentage\ power\ effiency\ of\ reactor$$
$$n_{active} = percentage\ of\ time\ over\ a\ year\ when\ reactor\ is\ in\ use$$
$$t_{yr} = number\ of\ hours\ in\ year = 8{,}760\ \frac{hours}{year}$$
$$Z = cost\ per\ kWh$$
m = Annual Cost of reactor losses in dollars/yr

$$m = \left(5000 * 0.95 * \frac{70}{100}\right) * \left(1 - \frac{98}{100}\right) * \left(8{,}760 * \frac{90}{100}\right) * 0.087$$
$$m = 45{,}612.88\ \frac{\$}{yr}$$

Break-even analysis - Calculation to determine the number of years until the CLiP current limiting protector becomes more cost-effective than a reactor:

$$C = \frac{A - B}{m}$$
$$A = Initial\ cost\ of\ CLiP$$
$$B = Initial\ cost\ of\ reactor$$

$$C = \frac{160{,}000 - 75{,}000}{45{,}612.88}$$
$$C = 1.86\ years$$

Crossover point - CLiP current limiting protector will become the more cost effective option after just 1.86 years of operation.

Current limiting protector cost savings over time - Calculation for estimating long-term cost savings of using CLiP current limiting protector:

$$D = m * t - A + B$$
$$t = number\ of\ years$$

$$D = 45{,}612.88 * 20 - 160{,}000 + 75000$$
$$D = \$827{,}257.64$$

Outcome - Over a span of 20 years, using CLiP current limiting protector instead of a reactor will generate total savings of $827,257.

Case Study: Managing high utility charges

A multinational pulp manufacturer was considering a reactor with a voltage rating of 13.8kV and a continuous current rating of 2000A. The reactor has a 99% efficiency, is expected to operate at 80% capacity during active periods, and remain active 50% of the year.

The utility charges the manufacturer 0.046 $/KWH and the plant operates at a power factor of 0.90. They received a G&W Electric CLiP current limiting protector quote for an approximate initial cost of $150,000 with an additional $45,000 in 3 CLiP current limiting protector spares for the worst-case scenario of a three-phase fault event. The reactor quote was $70,000.

How many years until the CLiP current limiting protector becomes more cost effective relative to the reactor? How much did the organization save by using a CLiP current

$$S = \sqrt{3} * \frac{13800V * 2000A}{1000}$$
$$S = 47{,}804.60\ kVA$$
$$m = \left(47{,}804.60 * 0.90 * \frac{80}{100}\right) * \left(1 - \frac{99}{100}\right) * \left(8{,}760 * \frac{50}{100}\right) * 0.046$$
$$m = 69{,}348.03\ \frac{\$}{yr}$$
$$C = \frac{195{,}000 - 70{,}000}{69{,}348.03}$$
$$C = 1.80\ years$$

Crossover point - In this case, even with an assumption of a worst case scenario, the CLiP current limiting protector will become the more cost-effective alternative in less than two years of operation.

$$D = 69{,}348.03 * 20 - 195{,}000 + 70{,}000$$
$$D = \$1{,}261{,}960$$

Outcome- Over a span of 20 years, using the CLiP current limiting protector will generate total savings of $1,261,960 vs the reactor alternative.

CLIP CURRENT LIMITING PROTECTORS: THE U.S. ADVANTAGE

Engineers in decision-making roles show a strong inclination (71%) for U.S.-made current limiting reactors. It could be that they favor domestic products for lower local maintenance costs, shorter lead time or tighter compliance with domestic regulations. But it's worth noting that 44% are also considering alternatives to reactors.

CLiP current limiting protectors are a U.S.-produced alternative which may have a slightly higher initial price, but a lower total cost of ownership for industrial, critical facilities, utilities and data center applications.

Source: Current Limiting Reactors Report, Prepared for G&W Electric by WTWH Media LLC.

CONCLUSION

Power is surging to meet unprecedented demand. While traditional reactors have been the "go-to" fault protection solution due to their initial affordability, their limitations can lead to significant cost inefficiency over time.

G&W Electric's CLiP current limiting protector offers a compelling alternative. These devices effectively limit both the magnitude and duration of faults, providing faster, safer and reliable fault clearing while reducing a wide range of costs. Mathematical models show that in a few short years they become the more profitable choice and an affordable solution for critical facility upgrades and retrofitting. Ultimately, choosing CLiP current limiting protectors over traditional reactors is not just about a strong ROI, but a strategic decision to balance safety, efficiency, and savings in a rapidly changing power environment.

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