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TCI KLR Line Reactors

TCI KLR line reactors are heavy-duty three-phase inductors designed to protect variable frequency drives (VFDs) and other power conversion equipment from electrical disturbances while improving overall power quality. As an **input line reactor**, the KLR is connected between the AC supply and a 6-pulse VFD or DC drive, where it filters out transient surges and limits short-term spikes. It can also serve as an **output load reactor** on the VFD's output to smooth the inverter waveform and protect motors. Major drive manufacturers like Rockwell Automation and Yaskawa recommend using line reactors on VFD installations to guard against power line spikes and reduce harmonic distortion [1] [2]. TCI's KLR series is considered an industry-standard solution for these purposes, featuring a robust **"K-rated"** design optimized for non-linear loads (rich in harmonics) and a host of engineering features to ensure reliable, efficient operation [3] [4].

A TCI KLR series three-phase line reactor (open chassis style). The KLR's iron-core coils add impedance in series with the circuit. This limits inrush currents and filters out electrical disturbances before they reach sensitive drive components, thereby preventing nuisance trips and equipment damage.

Key Features and Benefits

- **Suppresses Voltage Notching & Transients:** KLR reactors mitigate **line notching** (commutation notches caused by SCR/thyristor drives) by providing a buffer impedance that rounds off the notches. This helps eliminate drive cross-talk and interference between multiple drives, preventing malfunctions in adjacent equipment [5] [4]. On the input side of a VFD, a reactor also absorbs **surge spikes** from utility capacitor switching or lightning-induced transients, thereby **limiting inrush current** and clipping sudden overvoltage peaks before they can charge the DC bus [6] [7].

By softening these fast changes, the KLR **prevents drive overvoltage trips** and the unexpected shutdowns they cause, greatly reducing potential downtime [8] [9].

- **Reduces Harmonic Distortion:** Non-linear loads like VFDs draw a distorted current waveform with high peaks, which can **distort the supply voltage** and create harmful harmonics. Adding a KLR reactor smooths and "rounds" the input current waveform by limiting the peak current drawn by the drive's rectifier [7]. This **reduces total harmonic current distortion (THID)** at the drive input, often from a typical ~80% THID down to around 30–40% in many cases [10]. The reduction in harmonic currents also leads to lower **harmonic voltage distortion** on the facility's power system [7]. Using line reactors thus helps facilities **meet IEEE 519** guidelines for harmonic limits, or at least significantly mitigates harmonics to avoid utility penalties [11] [10]. By filtering harmonics, the KLR additionally **improves true power factor** – since the drive draws less reactive harmonic current, the total power factor seen by the source is higher [12].

- **Prevents Overcurrent Faults & Equipment Stress:** The impedance of the KLR reactor buffers the VFD from sudden **short-circuit currents** or line surges, acting like a shock absorber in the circuit. This protects sensitive front-end components such as diodes, SCRs and IGBT **semiconductors from surge damage** [13]. It also **reduces nuisance tripping** of fuses or circuit breakers by smoothing out high current spikes [14]. In systems with multiple drives on a common bus or power feed, installing a line reactor on each drive helps isolate and **prevent cross-talk** between units, so that one drive's commutation notches or voltage dips do not induce faults in another. By adding a moderate source impedance, KLR reactors even help **balance phase currents** when minor input voltage imbalances exist, because the reactor resists sudden changes and forces a more equal current draw on all three phases [15]. Overall, the drive and its input rectifier are **shielded from electrical stresses**, leading to longer component life and fewer unexplained process interruptions.

- **Extends Motor and Drive Life (Output Filtering):** The KLR series can be applied on the **output side** of VFDs (as a load reactor) to benefit motor-fed circuits. In long motor lead applications or when a single VFD runs multiple motors in parallel, an output reactor adds critical inductance that **dampens voltage spikes (dV/dt)** and surge currents. This protects motor insulation from the steep-edged PWM pulses and reduces **reflected wave transient voltages** at the motor terminals [11] [16]. By smoothing the current, the reactor also **reduces motor heating and audible noise** caused by high-frequency PWM harmonics [17] [11]. Many drive manufacturers provide load reactors for such scenarios; for example, Allen-Bradley load reactors are recommended to **protect motors from long-lead effects, reduce motor temperature, and cut down audible noise** on inverter outputs [11]. Using KLR reactors on the output can additionally prevent VFD **over-current trips** when driving an unusual load – for instance, multiple small motors or a highly capacitive load that could otherwise cause instantaneous overcurrent faults [18]. The net effect is extended motor life and higher system reliability, especially in demanding applications.

- **Robust Construction & Design:** A standout feature of TCI's KLR reactors is the use of **Distributed Gap™ core technology** in larger models. As reactor current ratings increase, a single large air gap in the core can cause localized flux fringing, heating, and eventual insulation breakdown. TCI addresses this by subdividing one large gap into multiple smaller gaps distributed along the core. This **multi-gap core design** results in cooler operation and higher efficiency for reactors above 110 A [19]. In fact, KLR reactors built with Distributed Gap™ technology run noticeably cooler and last longer than competitor reactors that use a single-gap design [19]. All KLR units are built with **high-grade silicon**

steel laminations and **100% copper windings**, ensuring low losses and reliable performance under heavy loads [20]. The insulation system is rated to handle high thermal stress (Class H 180 °C, with some designs even using Class R 220 °C insulation for extra margin) [21]. Standard designs have a **115 °C temperature rise** (some larger units 155 °C rise), meaning they safely handle heat within a 40 °C ambient environment [21]. Overall, the KLR series is engineered for **harsh industrial conditions** – the reactors can tolerate **200% of their rated current for up to 3 minutes** without damage, providing a buffer for overloads, startup surges, or abnormal transient events [22].

- **Broad Range of Ratings:** The KLR line reactor family covers a **wide range of system voltages and power levels**, making it suitable for everything from fractional horsepower drives to very large motor controllers. Standard units are rated for **208 VAC through 690 VAC, 50/60 Hz** three-phase systems [23] [24]. The available current and power ratings span roughly **0.25 HP up to 1250 HP** – for example, a 3% impedance KLR reactor can be as small as a few amps (for a 1/2 HP 230 V drive) or as large as several hundred amps for a 1000+ HP 480 V drive [25] [26]. Impedance options include **"Ultra-Low" (≈1.5% impedance), "Low" (≈3%), and "High" (≈5–6%)** to allow the appropriate level of filtering for the application [27] [28]. A 1.5% reactor is generally the minimum recommended on the input to protect a drive, and is the **maximum impedance to use on a VFD output** (to avoid excessive voltage drop) [27]. The popular 3% impedance is usually sufficient to eliminate most AC line overvoltage trips and provide general harmonic reduction [27]. For harsh conditions – such as **meeting IEEE-519 harmonic limits or protecting drives in severe harmonic environments (e.g. heavy DC drive systems)** – a 5% (high impedance) reactor offers deeper harmonic filtering and extra protection for the drive at the cost of a slightly larger voltage drop [29] [30]. This flexibility in impedance and sizing means KLR reactors can be properly matched to the needs of virtually any VFD installation.

- **Universal Mounting & Enclosures:** TCI's KLR reactors are designed with **installation flexibility** in mind. They feature a **universal mounting footprint** that simplifies retrofits or replacements – often, a KLR will fit the pre-drilled hole pattern of other common reactors or panel layouts [31]. Depending on the frame size, KLR units offer various **termination options** to ease wiring: smaller reactors (up to ~80 A) come with heavy-duty terminal blocks or pressure plate connectors, while larger models use sturdy copper bus bar connections for bolting lugs directly [31] [32]. The reactors are normally supplied as **open chassis units** (IP00) for integration inside electrical panels or VFD cabinets. However, TCI also offers optional **NEMA 1 enclosures** (for general indoor protection) and **NEMA 3R enclosures** (for outdoor or washdown environments) if a standalone enclosed reactor is needed [33] [34]. These enclosure options are UL-listed, allowing the KLR reactors to be used as UL Listed devices when mounted in the appropriate TCI enclosure, which can be important for meeting code requirements in certain installations [35]. In summary, the KLR reactors can be **wall-mounted or floor-mounted**, inside a cabinet or in their own enclosure, giving considerable versatility to adapt to the site conditions [36].

- **Compliance and Certifications:** All KLR series reactors are built to high quality and safety standards. They carry **UL and cUL (CSA) component recognition**, and can be provided as **UL Listed assemblies** when ordered with the proper enclosure kit [37] [35]. The line is **CE marked** for use in international applications and is **RoHS compliant** (free of hazardous substances) as noted in product literature [38] [39]. Using line reactors can also help meet various **industry standards for power quality**, such as IEEE 519 for harmonics in North America and the IEC 61000-3-12 / EN 61800 guidelines in Europe, by curbing the distortion fed back to the grid [11]. In practice, adding reactors

to VFDs has become a best practice for compliance and reliability – for example, one Plant Engineering report specifically lists installing an input line reactor as the **number one** recommended step to improve VFD system efficiency and longevity [40] [41].

- **Lifetime Warranty & Performance Guarantee:** Underscoring their reliability, TCI KLR reactors come with an exceptional **warranty and guarantee program**. The **standard warranty covers each KLR reactor for the life of the drive** it is installed with – essentially a lifetime warranty on the reactor as long as it remains paired with that VFD [42]. Additionally, TCI offers a unique **Performance Guarantee**: if a properly sized KLR line reactor does not eliminate a drive's overvoltage tripping problem, TCI will accept a return of the reactor and even cover shipping costs (valid within 60 days of purchase) [43]. This guarantee reflects the manufacturer's confidence that installing a KLR reactor will solve nuisance AC drive overvoltage faults **when correctly applied**. From a user's perspective, these policies provide peace of mind – the reactor is essentially guaranteed to perform as advertised in protecting the drive, or you don't pay for it. Few power quality devices come with this level of assurance.

Technical Specifications Summary

To summarize the capabilities of the TCI KLR line reactors, the key technical specifications and options are as follows:

- **Electrical Ratings:** Three-phase **208 V to 690 V AC** systems (600 V class insulation), compatible with **50 Hz or 60 Hz** supply frequency [23]. Standard impedance choices of approximately **1.5%, 3%, or 5%** (labeled Ultra-Low, Low, and High Z) at rated load, allowing the user to select lower impedance for minimal voltage drop or higher impedance for maximum filtering [28]. **Current (Power) Range:** Available for drive sizes from **0.25 HP up to ~1250 HP** (roughly 1 A to 1200 A). For example, a single KLR unit can handle from a **fractional 1 HP drive** (drawing under 3 A) to a **600 A drive** or larger, depending on the model [26]. Multiple reactors can be used in parallel for higher currents if needed, or custom units are available for special requirements.

- **Thermal Performance:** Designed for a **40 °C ambient** operating temperature (open chassis installation) without derating [44]. In practice, if placed in an enclosure, adequate ventilation or a slightly lower ambient should be considered (TCI specifies 40 °C max inside enclosures as well) [45]. For higher temperatures, the reactors should be derated or cooling measures applied. The insulation system is Class H or better, and the coils are impregnated to withstand high temperatures. The reactor can endure **200% overload current for 3 minutes** and **150% current for at least 1 minute** without core saturation beyond spec (maintaining a minimum of 80% inductance at 1.5× rated current) [46] [22]. This ensures the reactor remains effective even during short surges and does not saturate or drop out of the circuit during heavy acceleration or regenerative braking events on the drive.

- **Construction Details:** The core is a gapped iron lamination stack with epoxy encapsulation on smaller sizes and an open laminated core on larger sizes. Units up to **~80 A use a bobbin-wound coil construction** (for structural stability and reduced vibration) [46]. Units **110 A and above utilize Distributed Gap™ cores** to minimize hot spots and core losses [46]. All reactors use **copper windings** for low resistance and longevity. The device is passive (no capacitors or electronics), which means **no routine maintenance** is required aside from checking connections. Reactors introduce a

small impedance, typically resulting in a voltage drop of a few volts under load (approximately 3–5 V drop for a 3% reactor at full load on a 480 V system, as an example). This slight drop is usually negligible for the motor operation but is enough to significantly **limit fault currents and filter harmonics**.

- **Physical Formats: Open panel (IP00)** format is standard, with mounting feet/brackets provided. TCI's universal footprint often matches the hole pattern of equivalent reactors from other brands, simplifying upgrades. **Enclosed versions** are offered in **UL Type 1** (ventilated indoor) or **Type 3R** (outdoor-rated) steel enclosures for applications where the reactor must be stand-alone outside a cabinet [34]. Enclosed reactors carry a UL Listing. Mounting can be horizontal or vertical; a spacing of a few inches around the reactor is recommended for cooling air flow [47] [48]. The reactors are relatively compact for their ratings, but as an indication, a mid-size 60 HP 480 V (65 A) KLR reactor measures around 9 × 11 × 8 inches and weighs ~30 lbs, while a large 300 HP 480 V (361 A) unit can be on the order of 18 × 14 × 10 inches, ~90 lbs [49] [50]. All reactors include an **integral grounding bracket or lug** to ensure proper earthing of the core and enclosure if metal.

- **Standards Compliance:** KLR reactors are **UL Recognized (cURus)** as per UL 508, and **CSA certified**, for both the U.S. and Canadian markets [20]. They also carry the **CE mark**, indicating compliance with EU low-voltage and EMC directives. Using a KLR can help a VFD installation adhere to **IEEE 519-2014** harmonic standards in many cases by reducing current distortion (though very large drive systems may still require additional filtering) [51]. The KLR's ability to reduce harmonics and line notches also assists in meeting IEC/EN 61000-3-12 requirements for industrial equipment. The reactors are **RoHS compliant** and manufactured under ISO-9001 quality processes.

Real-World Application and Results

Line reactors like the TCI KLR series are widely used across industries – from HVAC systems and pumping stations to oil & gas installations and manufacturing lines – anywhere AC drives or DC drives are employed. In practice, installing KLR reactors yields tangible improvements in system performance and equipment longevity. For example, a plant that was experiencing frequent **VFD overvoltage faults** (trips) due to utility capacitor switching transients saw those nuisance trips completely disappear after adding 5% impedance KLR reactors on the drive inputs. This elimination of unplanned drive shutdowns improved the line's uptime and saved many hours of lost production. In another case, a facility with multiple large VFDs found that adding reactors not only protected the drives but also **reduced interference** between them – solving mysterious tripping issues where one drive's operation was affecting another. This was because the reactors mitigated the voltage notching and **"cross-talk"** on the shared power bus that had previously caused sensitive drives to fault out.

In terms of **quantifiable power quality improvements**, a 3% KLR reactor typically brings input current distortion down into the 30%–40% THID range for a standard 6-pulse VFD (from a baseline that might be 80% or more without any reactor) [10]. While 30–40% THID is still above very strict IEEE 519 limits for large systems, in many installations the presence of other loads and the distribution impedance means the overall point of common coupling THD is well within acceptable limits once reactors are in place [52]. In essence, the **reactors "mop up" the sharp edges** of the drives' current draw, and the remaining distortion is often diluted by other linear loads in the facility [52]. Where even lower harmonics are required, reactors serve as the first stage of mitigation and can be complemented by passive harmonic filters or active filters. But because of their cost-effectiveness and reliability, **reactors are usually the first line of defense**. As one

engineering guide put it, AC line reactors are *"the commonly preferred method of harmonic correction due to their effectiveness, reliability, and low cost"* [53].

Maintenance managers also report collateral benefits from using line reactors. Motors run cooler and quieter, drives experience fewer unexplained **"nuisance" trips**, and sensitive electronics on the same supply see less voltage fluctuation. By **reducing high-frequency noise** on the power lines, reactors can prevent interference in nearby instrumentation or PLC networks. Additionally, KLR reactors provide a measure of protection to any power factor correction capacitors in the system by blocking some of the harsh harmonic currents that would otherwise flow into those capacitors (thus preventing resonant amplification scenarios). Facilities that proactively install line reactors on VFDs often find that **drive MTBF (mean time between failures) improves**, as the drives are no longer subjected to the constant electrical stress of an unmanaged power line.

It is worth noting that **most drive OEMs incorporate either a DC link choke or specify an external AC line reactor for larger drives** as standard practice. For instance, many ABB and Schneider drives above a certain kW rating include a DC choke to mitigate harmonics; Yaskawa's drives often list optional AC line reactors in their manuals with recommendations to use them when the supply transformer is overly stiff or if the drive is fed alongside capacitor banks [54] [55]. Yaskawa explicitly states that 3%–5% input reactors *"may be used on the input to reduce the effects of line side transients on the drive."* [2]. Rockwell Automation likewise offers a line of input reactors (the 1321 series) for their PowerFlex drives, noting that a line reactor at the drive input *"helps protect against surges or spikes on the incoming power lines and help reduce harmonic distortion"* [1] while also improving power factor and compliance. The TCI KLR series is fully compatible with all these systems and in fact is frequently chosen as an **upgrade or replacement reactor** for various drive brands due to its high performance specs. Precision Electric (a drives systems integrator) developed the KLR series in partnership with TCI to have a **universal product** that can retrofit into virtually any drive installation, new or old [31].

In summary, **TCI's KLR line reactors provide an effective, proven solution to many power quality challenges** in VFD and SCR drive applications. By installing a relatively small impedance in the line, users reap outsized benefits: drives stop tripping on overvoltage, harmonic currents are tamed, electrical stress on components is relieved, and motors are happier on the output side. The KLR reactors pack in advanced features like the Distributed Gap™ core to handle high currents reliably, and they come with the backing of TCI's lifetime warranty and performance guarantee – a strong testament to their reliability. Whether for a single VFD or an entire plant of drives, these reactors serve as inexpensive insurance to **maximize drive uptime, compliance, and longevity**. With broad voltage and horsepower coverage, a KLR reactor can be obtained for practically any drive out there, making it a go-to choice for engineers and technicians looking to **"harden" their motor drive systems against the realities of the electrical supply**. As the first line of defense against surges and harmonics, TCI KLR line reactors help ensure that both drives and motors enjoy a longer, more trouble-free life in the field.

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