

REINHOLD ENVIRONMENTAL Ltd.



**2017 APC & Wastewater Round Table
& Expo Presentation**

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ESP Current Limiting Reactor (CLR) Sizing

Mike Afflerbach, Magnetic Specialties –
Telford, PA

Dan Steinhaur, Stein Industries – London,
Ontario



Mike Afflerbach - Magnetic Specialties

- BSEE, Pennsylvania State University
- 23 years experience designing transformers and reactors
- Currently President, Magnetic Specialties, Inc.
- MSI privately held, one of the Solar Atmospheres group companies
- MSI founded 1956 in Trenton, NJ by William Byrd, one of the first companies to produce ESP controls



Dan Steinhaur – Stein Industries

- BAsC Electrical Engineering University of Waterloo, Waterloo Ontario Canada 1980
- 24 years experience designing transformers and reactors
- President and owner of Stein Industries Inc.
- Prior experience 4 years with Westinghouse, ABB product manager of Precipitation Products Group



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Where are CLR's used?

- Line frequency (50 and 60 Hz) TR controls in primary circuit
- Mid frequency (100 to 800 Hz) TR controls between H-bridge and transformer primary



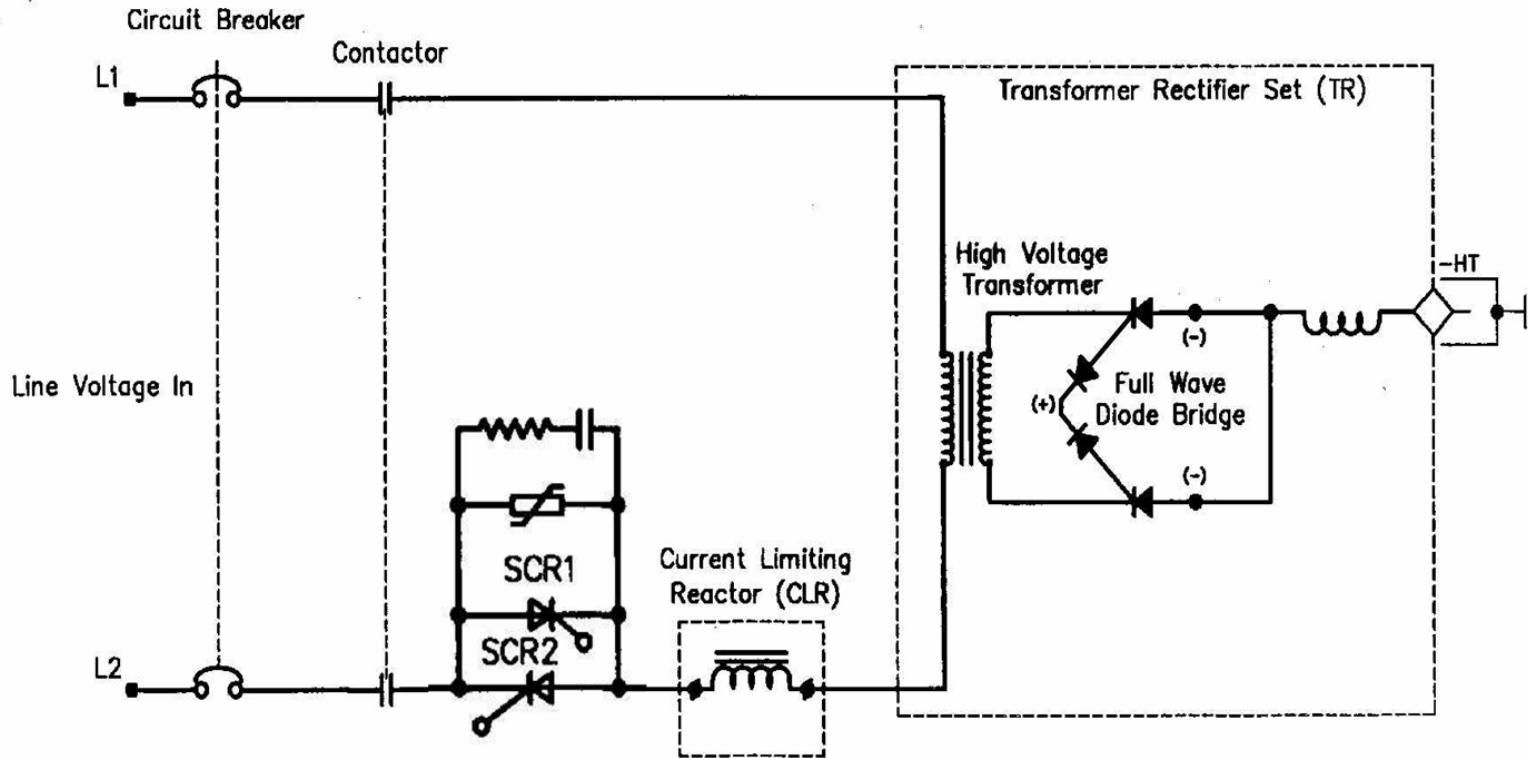
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Line Frequency TR Control



Mid Frequency TR Control

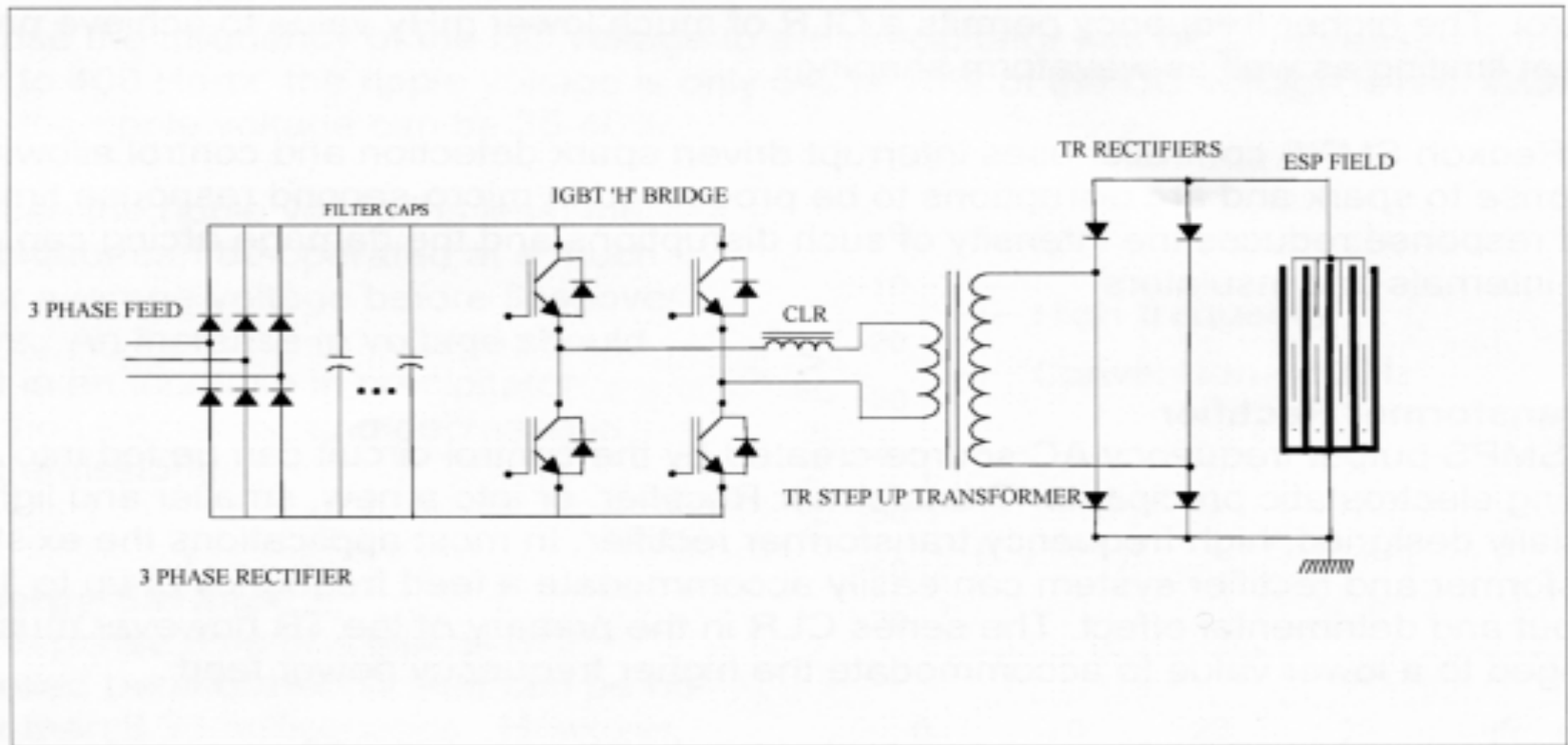


Figure 1



What does a CLR do?

- Provides a means for limiting instantaneous current rise in TR primary
 - Smooths chopped current to more closely resemble a sinewave
 - In extreme situations acts as ballast to limit short circuit current to protect equipment
- Allows the TR set to be impedance matched to ESP load
 - By adding impedance in TR primary allows for smoother controls operation
 - Reduces high peak currents and lowers losses(heating) in TR and cabling



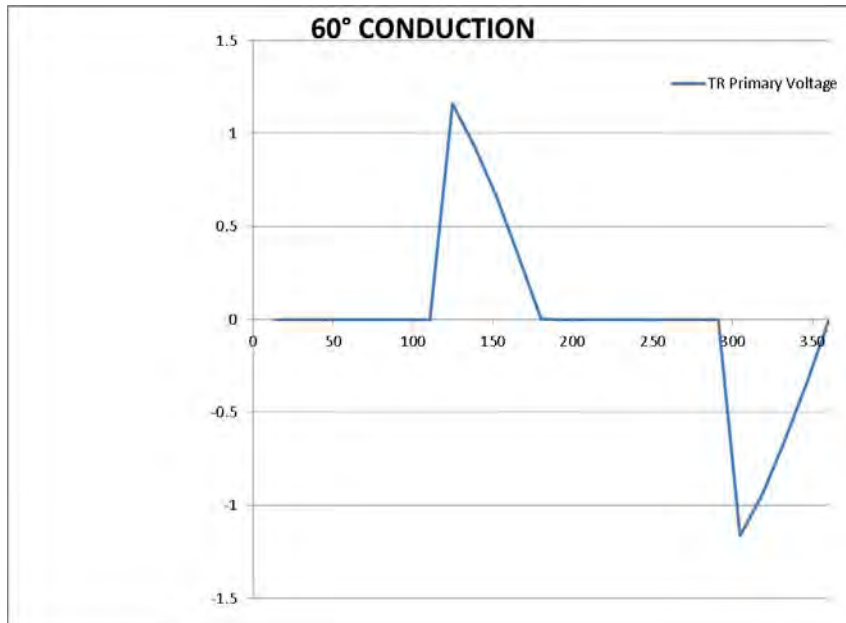
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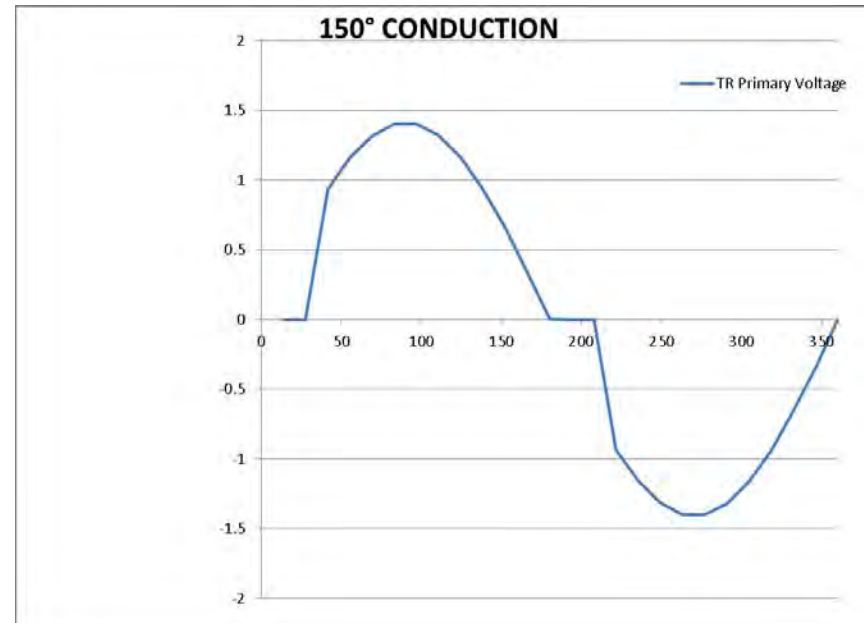


TR Primary Voltage Waveforms

No CLR or Improperly Sized



Properly Sized CLR

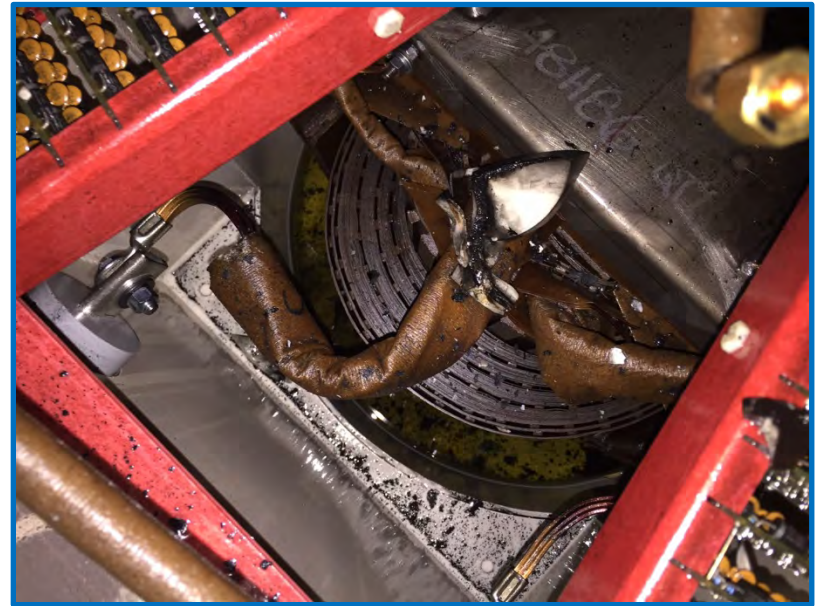


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TR Damaged Due to No CLR



Pictures Courtesy of



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Electrical Properties Required

- Maintain inductance throughout entire operation cycle
 - Peak currents can be 3-4 times nominal
- Be able to withstand frequent voltage transients due to sparking and arcing of ESP load
- Carry harmonic rich current without overheating
- Designed for proper line voltage to ground isolation



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Physical Properties Required

- Windings and core must be braced for transient forces
- Be designed to cool and not exceed insulation temperature rating, includes proper cabinet ventilation
- Enclosure must be designed to protect from environmental hazards and safety
 - Rain water and/or dripping from equipment cooling water
 - Chemicals, dust, and corrosives
 - Incidental contact of live parts



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CLR Damaged Due to Inadequate Ventilation



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General Types of CLR

Iron Core

The most prevalent in ESP

- Advantages
 - Little to no external magnetic field
 - Can typically be a smaller total package (CLR/enclosure) than air core
- Disadvantages
 - Core will saturate at elevated currents and inductance will fall off
 - Heavier than air core
 - Core can become noisy over time if not properly braced

Air Core

Very rarely used in ESP

- Advantages
 - No saturation
 - Most often lighter in weight
- Disadvantages
 - External magnetic field requires physical clearance minimums
 - Typically more conductor to achieve same inductance resulting in higher losses
 - Larger total footprint



So, How Does One Size a CLR for ESP?

- I can't fully answer this question
- CLR should be sized by the controls OEM after site/process evaluation
- OEM generates a specification for CLR manufacturer to design a unit tailored for the application
- Bypassing a site evaluation can lead to an improperly sized CLR and result in early failure



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Information Required to Design CLR

- Electrical Parameters
- Physical and Environmental Parameters
- Preferences
- Regulatory Approvals



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Electrical Parameters

- Inductance and tolerance, typically +/-5%
 - Multi-tap or single tap
- Nominal current
 - If multi-tap is current different depending on tap
- Overload situation where inductance must be held to
 - Actual overload current
 - Per unit over nominal
 - Maximum voltage across CLR
- Frequency, may need to support multiple
- System voltage and if any special isolation voltage must be designed for



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Physical and Environmental Parameters

- Ambient temperature and altitude
- For existing cabinet installs
 - Physical constraints
 - How much ventilation available
 - Is unit going in tank with TR?
- If being supplied in enclosure what type is required
 - Indoor
 - Outdoor
 - Dust proof
- Whether gases or chemicals are a concern
 - Possible degradation of equipment
 - Ignition of gases from spark



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Preferences and Regulatory Approvals

- Winding material
 - Copper
 - Aluminum
- Whether a lower temperature rise than normal is required
- Type of cooling
 - Natural convection
 - Forced cooling
 - Under oil how much heat loss is tolerated
 - Water cooled
- UL, CSA, CE, etc.



CLR Acceptance Testing

- Routine Tests (Performed on all units)
 - Inductance at nominal current
 - Noise level measurement at nominal and overload current
 - Applied potential (Hi-pot)
 - Winding resistance
 - DC megger to ground
- Design Tests in addition to routine (Performed on first article)
 - Inductance at overload condition
 - Temperature rise performed as close to real world situation as possible
 - Phased back waveform or add additional losses for harmonics
 - Done in enclosure if supplied
 - Determined by change in winding resistance once thermocouples have settled
 - Correct rise to maximum ambient
 - Verify heat loss from temperature rise to design value

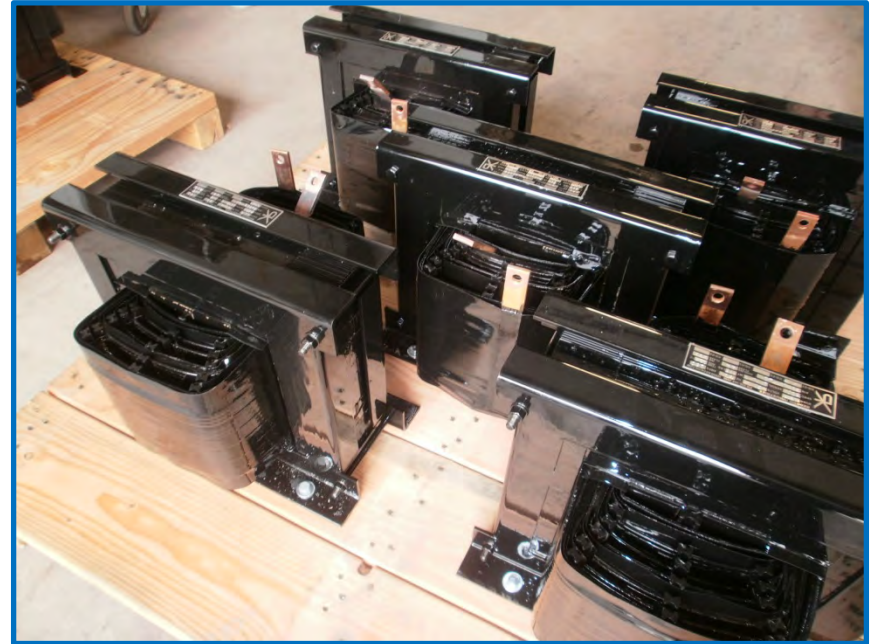


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Example CLR's



Enclosures

