REINHOLD ENVIRONMENTAL Ltd.

2018 APC & Wastewater Round Table & Expo Presentation

July 23 & 24, 2018 in Lexington, KY / Hosted by East Kentucky Power Coop

Transforming the Future of Power Technology

ESP Power Supplies & Controls 101

Transforming the Future of Power Technology

Objective

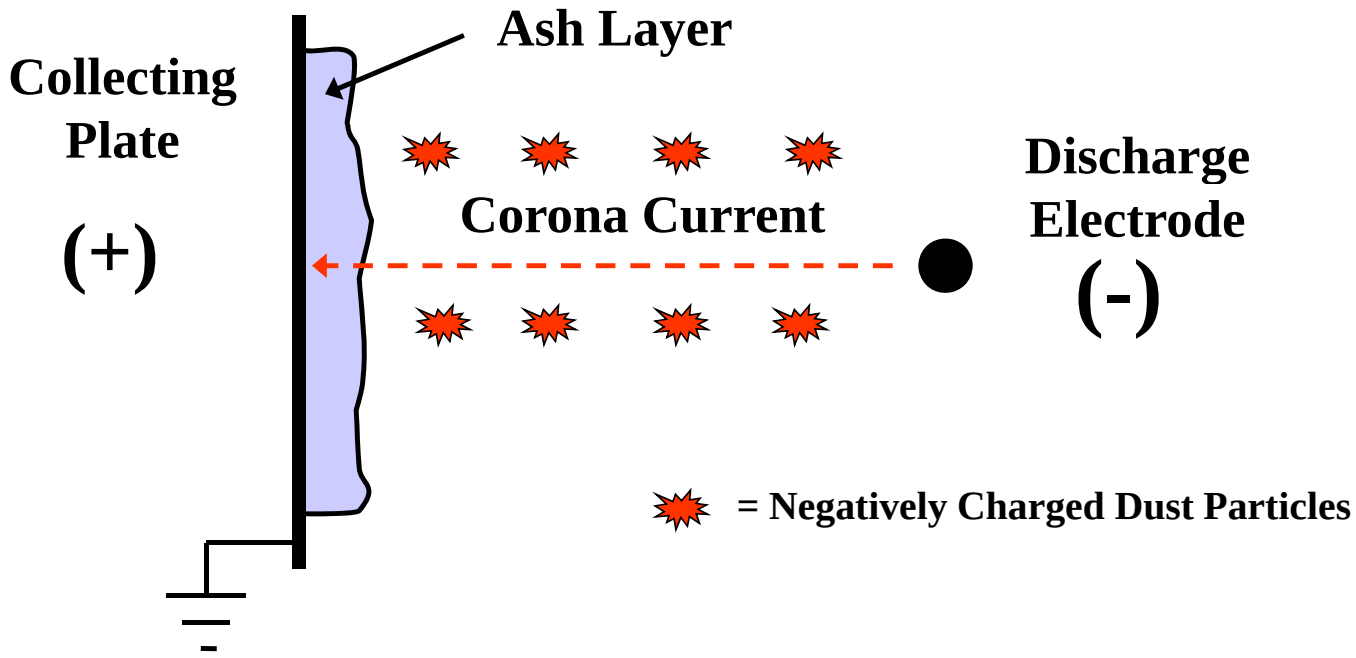
The purpose of this class is to provide a basic understanding of the power supplies used on Electrostatic Precipitators. It is geared for the ESP entry level personnel. We will cover the following topics:

- **Primary Function of the Power Supply**
- **Primary Function of the Control**
- **Power Supply Types Currently Available**
- **Spark/Arc Detection**
- **Voltage Optimization**
- **Basic Troubleshooting**

The primary function of the power supply is:

To provide a source of High Voltage for the Discharge Electrodes in the ESP

This high voltage charges the ash particles for the collection process.



The primary function of the control is:

1. **To prevent the power supply from operating at levels above it's nameplate rating.**

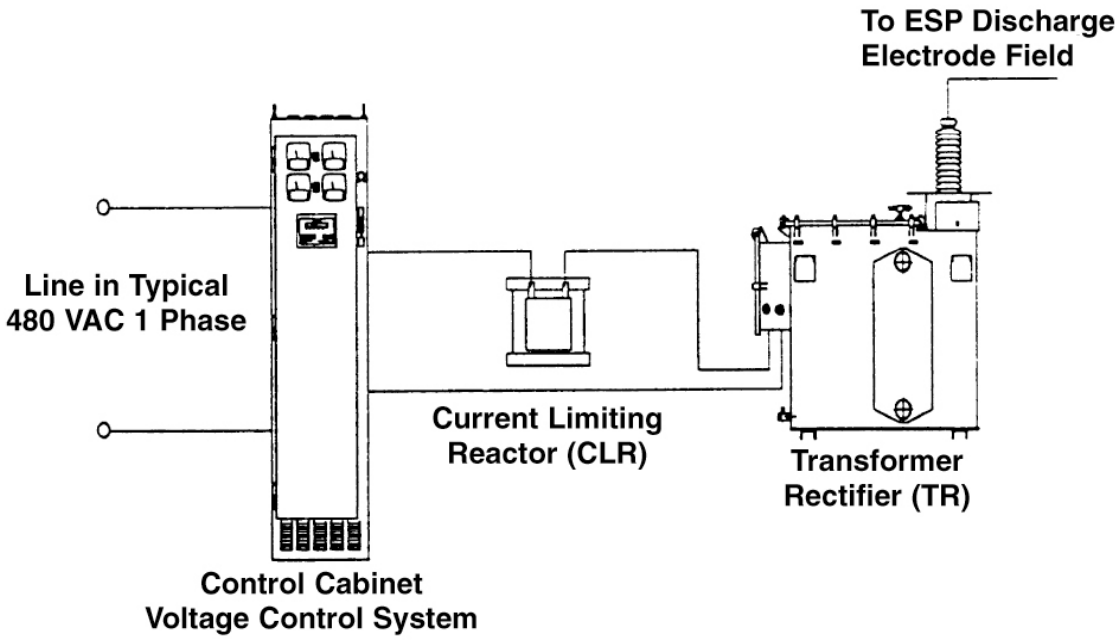
2. **To protect the power supply from varying load conditions within the ESP, such as short circuits, open circuits, and sparking/arcing.**

3. **To provide the highest possible voltage to the ESP for any given load condition.**

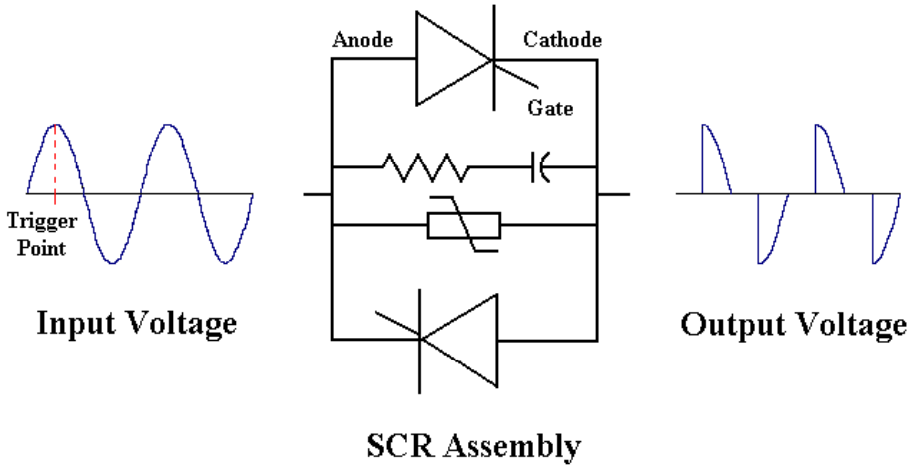
Power Supply Types Available:

- **Single phase T/R Set with CLR and SCR control**
- **Three phase T/R Set with CLR and SCR control**
- **Switchmode power supply utilizing IGBT's to generate high or mid frequency output to a T/R set.**
- **Pulser unit that generates a narrow high voltage pulse that gets imposed on a base high voltage waveform.**

- **Single phase T/R Set with CLR and SCR control**



- **Utilize Silicon Controlled Rectifiers (SCR) to vary the 480 VAC power**

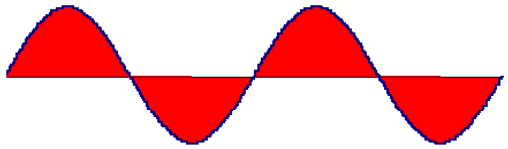


Two conditions must be satisfied for the SCR to conduct.

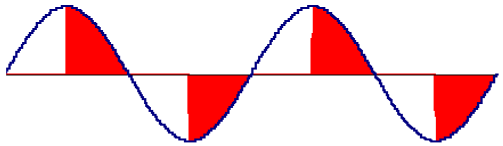
- **The anode of the SCR must be positive with respect to the cathode.**
- **A trigger signal must be applied to the gate.**

The SCR will continue to conduct until the current passing through it, goes to zero.

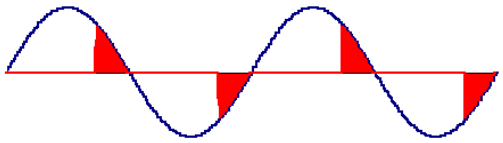
- **By varying the time delay between when the voltage goes positive and the trigger is applied, the output of the SCR will change.**



180 ° **Maximum Output from the SCR Assembly**

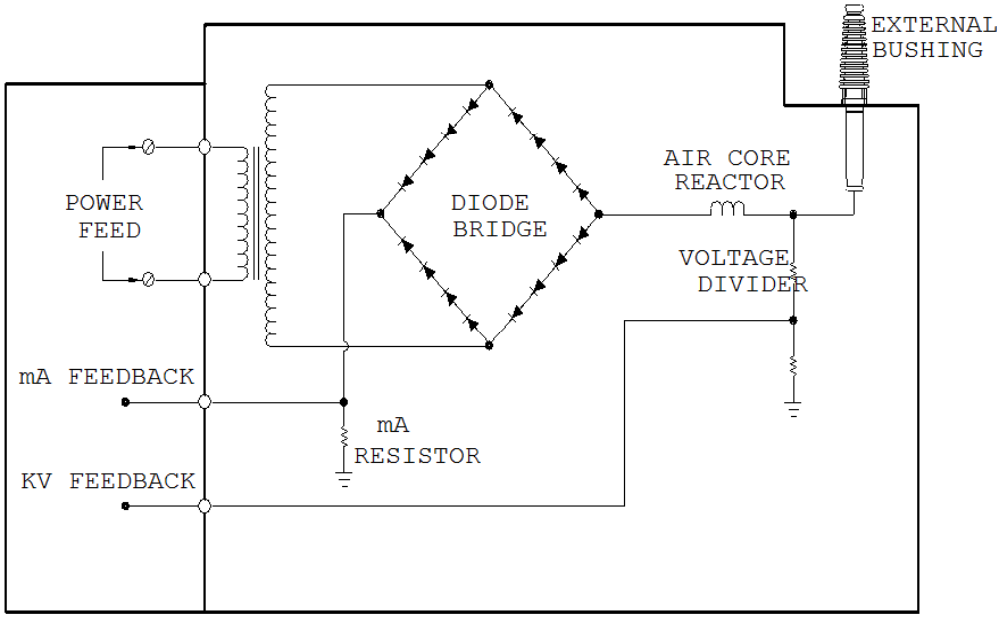


90 ° **Approx. Half Output from the SCR Assembly**



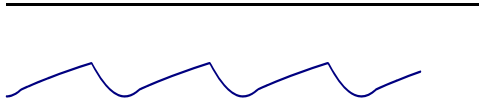
45 ° **Approx. Quarter Output from the SCR Assembly**

- **The varying 480 VAC gets sent to the T/R set**

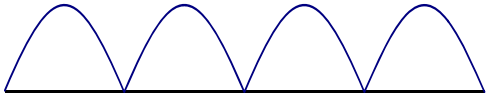


Output Waveform

kVDC



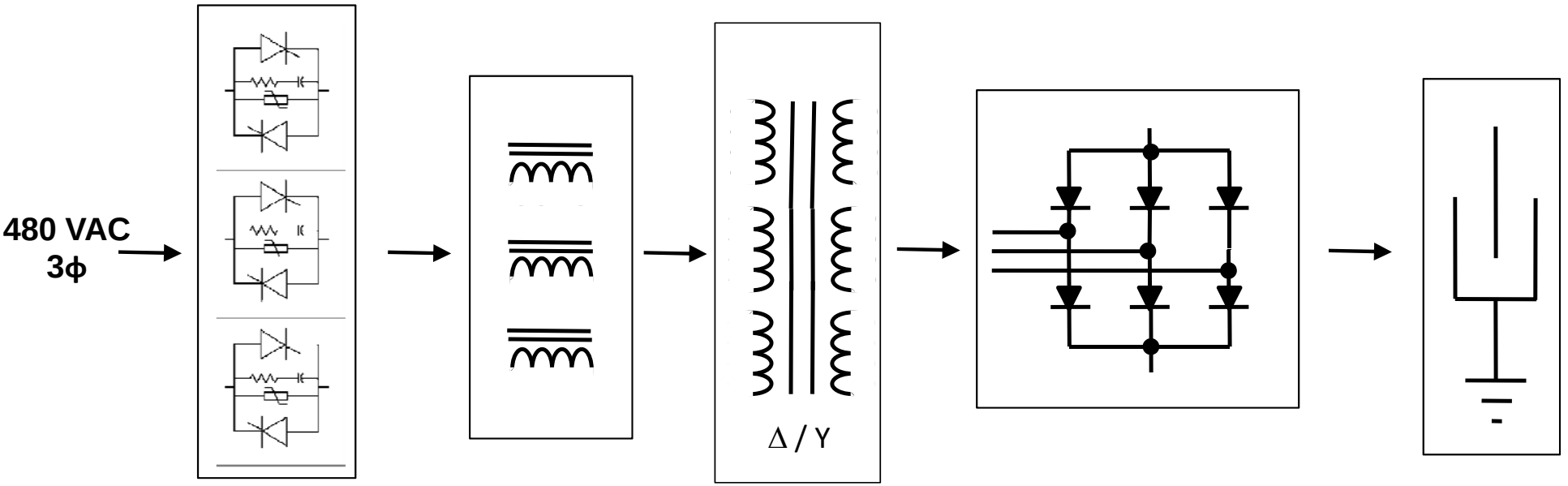
mADC



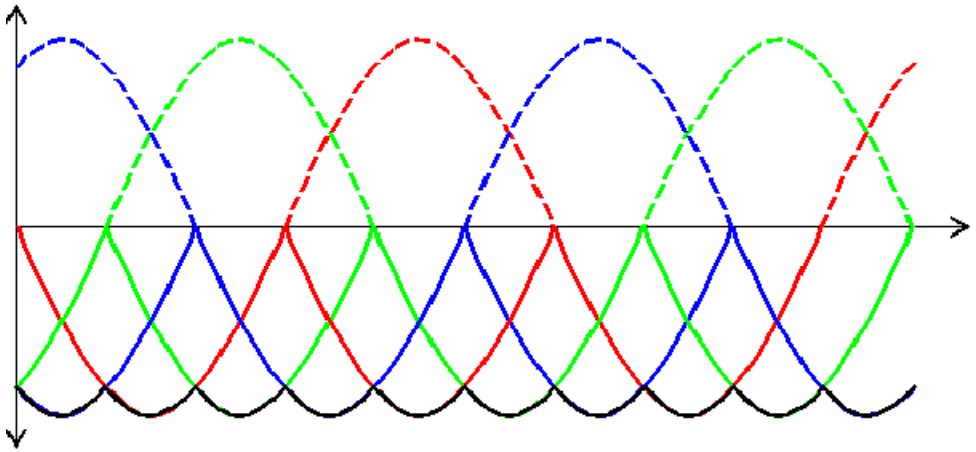
% Ripple kVp-p = approx. 35% - 45% depending upon load & SCR conduction angle

Ripple Frequency = 120 Hz for 60 Hz supply

- **Three phase T/R Set with CLR and SCR control**



Output Waveform

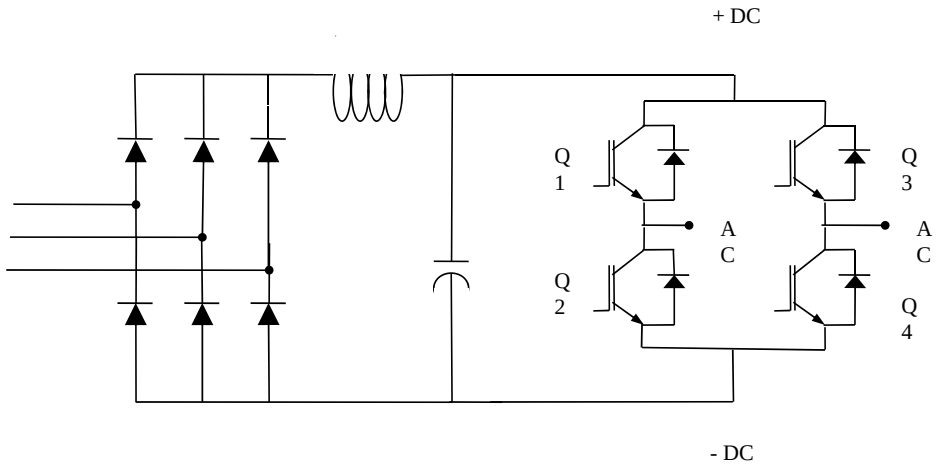


% Ripple kVp-p = 5% - 15% depending upon load and SCR conduction angle

Ripple Frequency = 360 Hz for 60 Hz supply

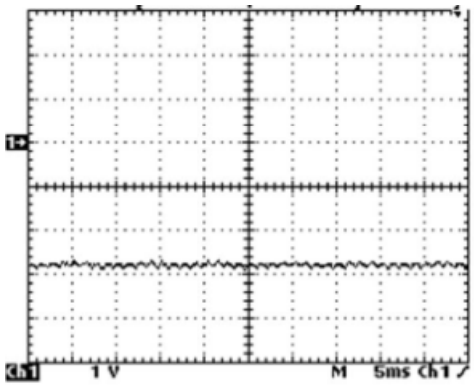
- **Switchmode Power Supply – includes mid frequency & high frequency units**

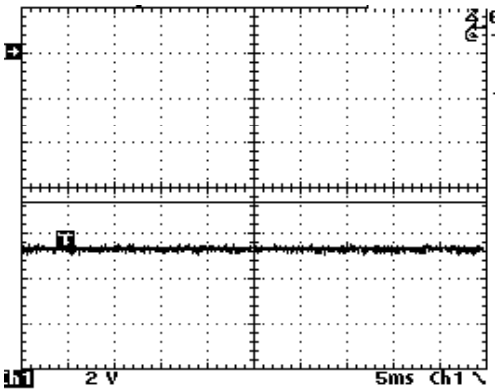
They utilize IGBT's (Isolated Gate Bi-polar Transistors) to convert to higher than line frequencies



The IGBT is a power electronic solid-state switch that turns on and off with very low power input yet switches high values of current and voltage. The IGBT can switch at many tens of kHz.

Output Waveforms





Mid frequency – 400 Hz

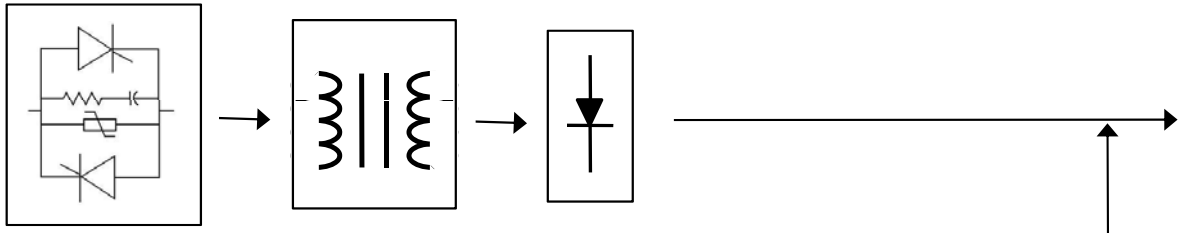
%Ripple kVp-p = 5-7%

High frequency – 25 kHz

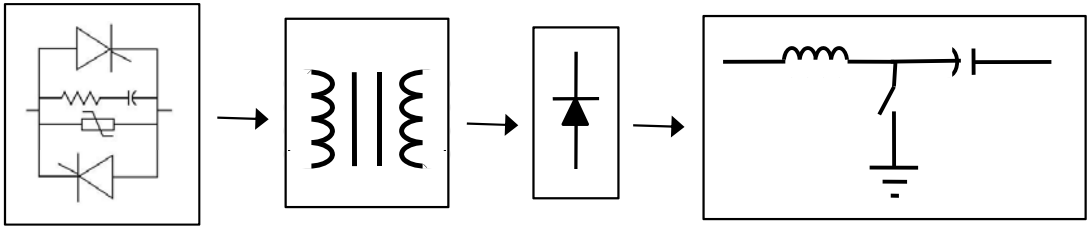
%Ripple kVp-p = 3-5%

Pulsers

Starts with a base HV output from a T/R set

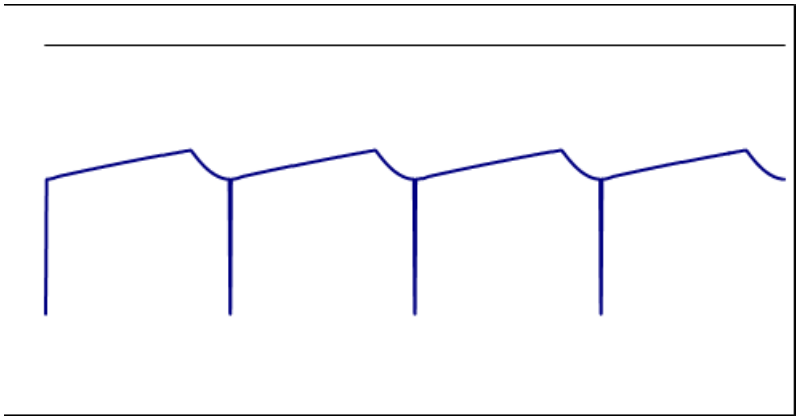


Imposes high frequency pulses on the base waveform



Primarily used for high resistivity loads where back corona is present

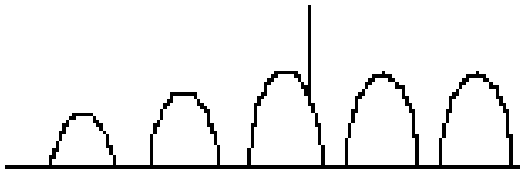
Output Waveforms



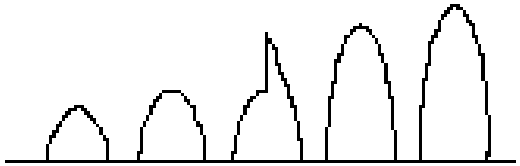
Spark/Arc Control: (Note: as each control manufacturer tends to have their own specific spark/arc definitions, parameter terms, and control responses, this portion will be based on the NWL control.

Definitions (shown with SCR waveforms):

Spark - A relatively small discharge within the precipitator that will self extinguish with no increase in the base waveform current.

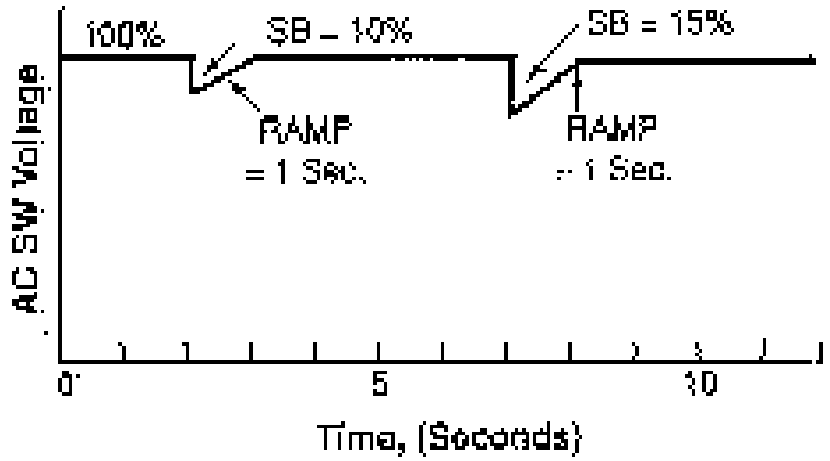


Arc - A large disruptive discharge within the precipitator that will not self extinguish. It causes continual fault current to flow.



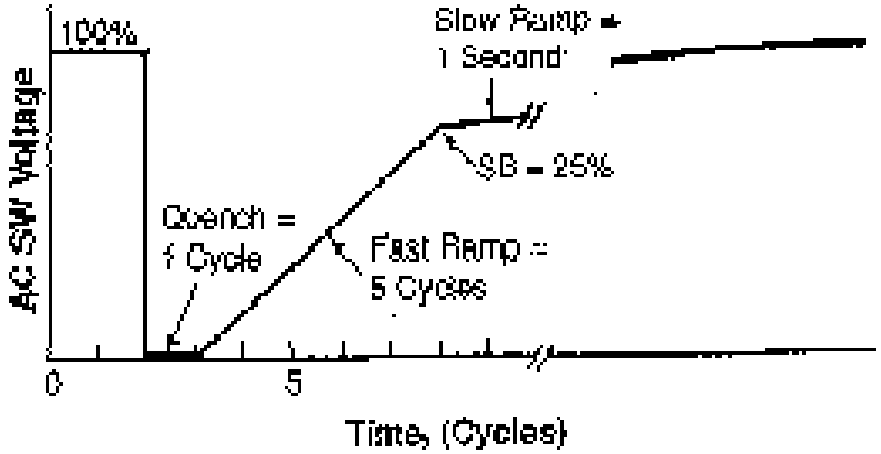
Spark Response

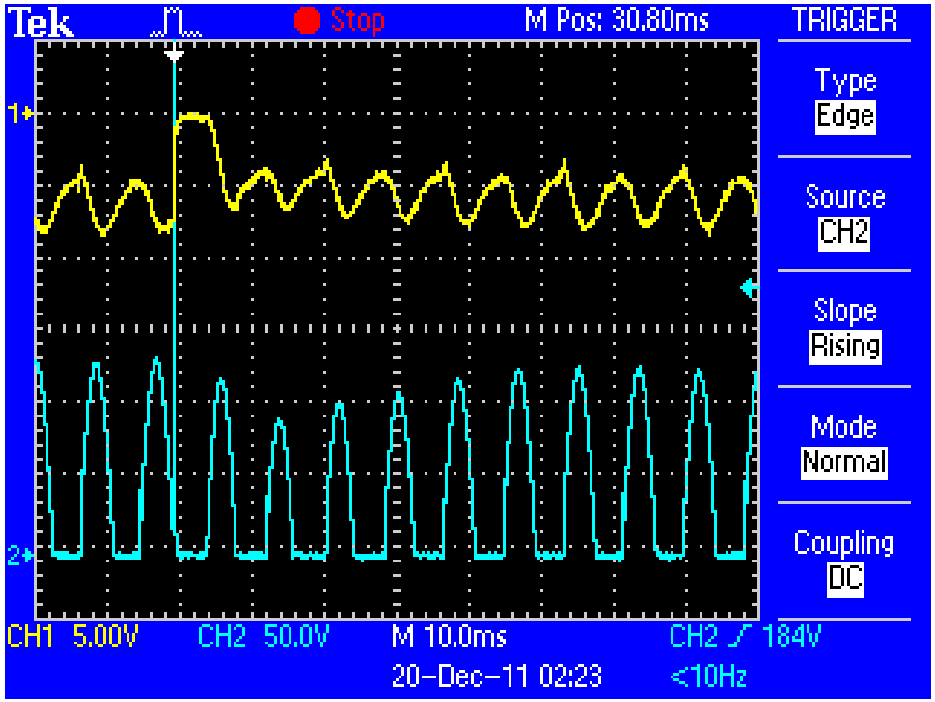
The conduction angle of the SCR's is reduced an adjustable amount on the next half cycle. This "setback" will reduce the KVDC in the precipitator so as to stop another spark from occurring. A "slow ramp" then increases the voltage back to the original sparkover point.



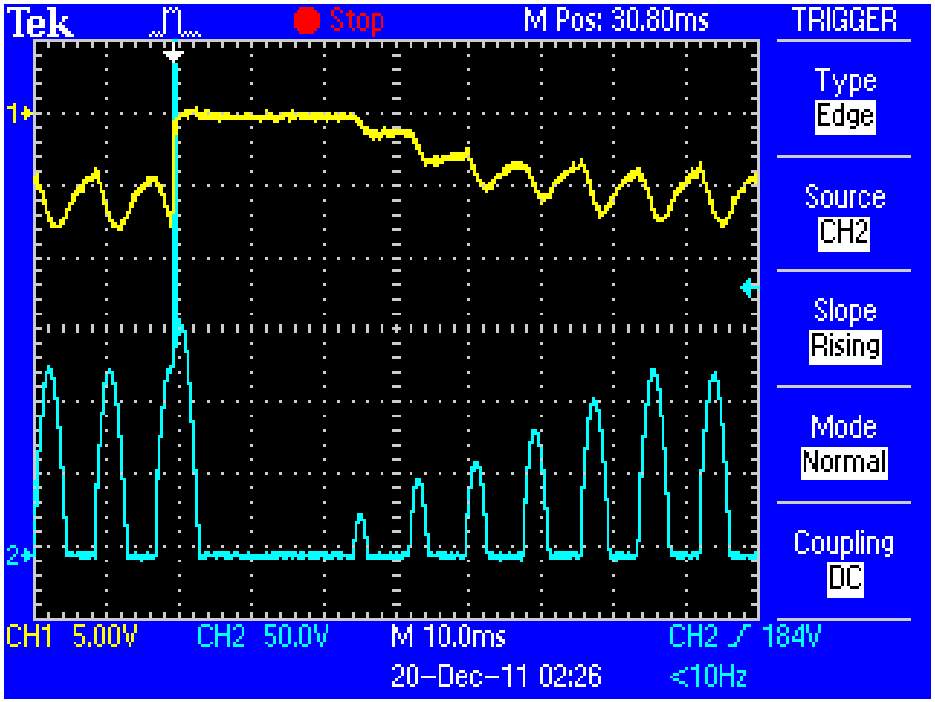
Arc Response

The SCR's are turned off during the next half cycle. They stay off for the duration of the quench time. This reduces the KVDC to zero allowing the arc to extinguish or "quench" itself. A "fast ramp" then quickly increases the voltage to the "spark setback" level where the "slow ramp" then increases it back to the arc over voltage.

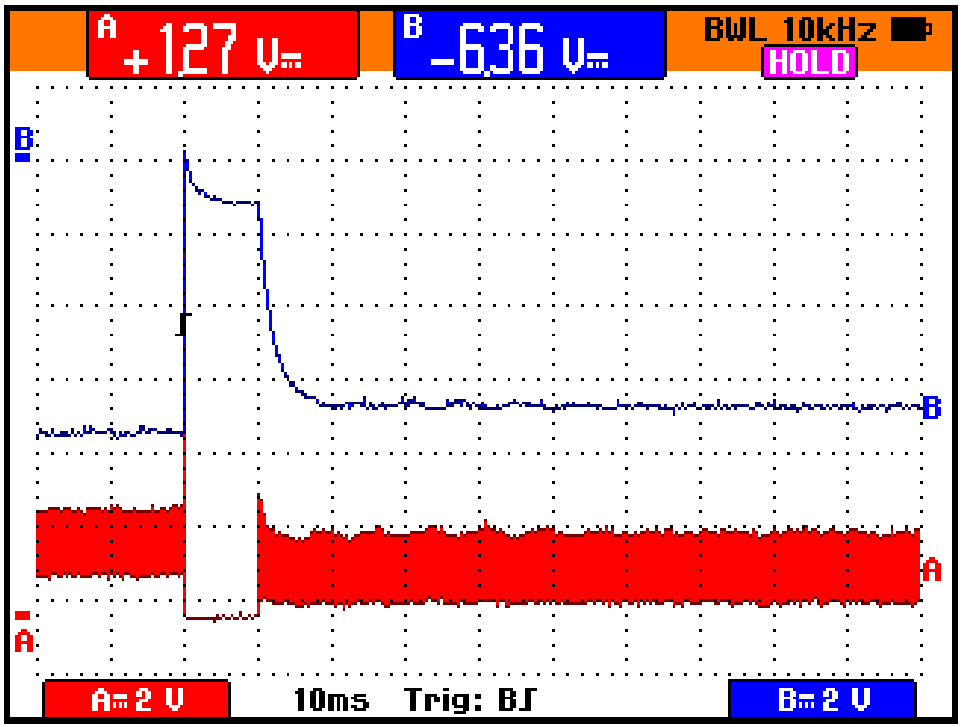




SCR Control Spark Response



SCR Control Arc Response



Switchmode Spark Response

Voltage Optimization

- **Precipitator efficiency increases as the average operating voltage increases.**
- **The highest voltage that a precipitator can withstand is the sparkover voltage.**
- **The sparkover is actually occurring at the peak of the kV waveform.**
- **So higher efficiencies can be obtained by using a power supply that provides low ripple output since the average kV is higher for the same peak value.**
- **Regardless of the circuit topology, the controller will try to maintain the highest possible voltage that the load conditions will allow by increasing the output until:**
  - ✓ **A spark/arc occurs**
  - ✓ **Voltage limit is reached**
  - ✓ **Current limit is reached**
  - ✓ **Maximum conduction of the SCR's or IGBT's are reached.**

Troubleshooting

Meter Readings:

VAC	LOW	LOW	LOW	HIGH
AAC	LOW	HIGH	HIGH	LOW
KVDC	LOW	LOW	LOW	HIGH
mADC	LOW	HIGH	LOW	LOW

Problem:
No power to T/R set

Tests:
1. Check if controller is responding to sparking. If it is, use a scope to verify that sparks/arcs are occurring. Run T/R with precip. disconnected to verify that T/R is not sparking internally.
2. Check for open SCR fuses.
3. Verify that SCR's are firing.
4. Check for open CLR.
5. Check for proper operation of controller power components.
   a. circuit breaker
   b. contactor

Problem:
Short Circuit - DC Side

Tests:
1. Run T/R set with HV bushing disconnected from the precip.
   a. If no current flows the short in the precip.
   b. If current still flows the short is in the T/R set.
2. If precip. is shorted, check electrodes and insulators for shorts.
3. If T/R is shorted, check HV bushing and external switch (if applicable) for shorts.

Problem:
Short Circuit - T/R Set

Tests:
1. Megger diodes for shorts.
2. Run T/R without diodes
   If AAC still high, transformer is bad.

Problem:
Open Circuit

Tests:
1. Run T/R set with HV bushing grounded externally.
   a. If current flows, precip. field is open.
   b. If no current flows, T/R is open.
2. If precip. is open, check all HV connections to electrodes.
3. If T/R is open, megger unit. check for open diodes or connections in T/R tank.

Thank You