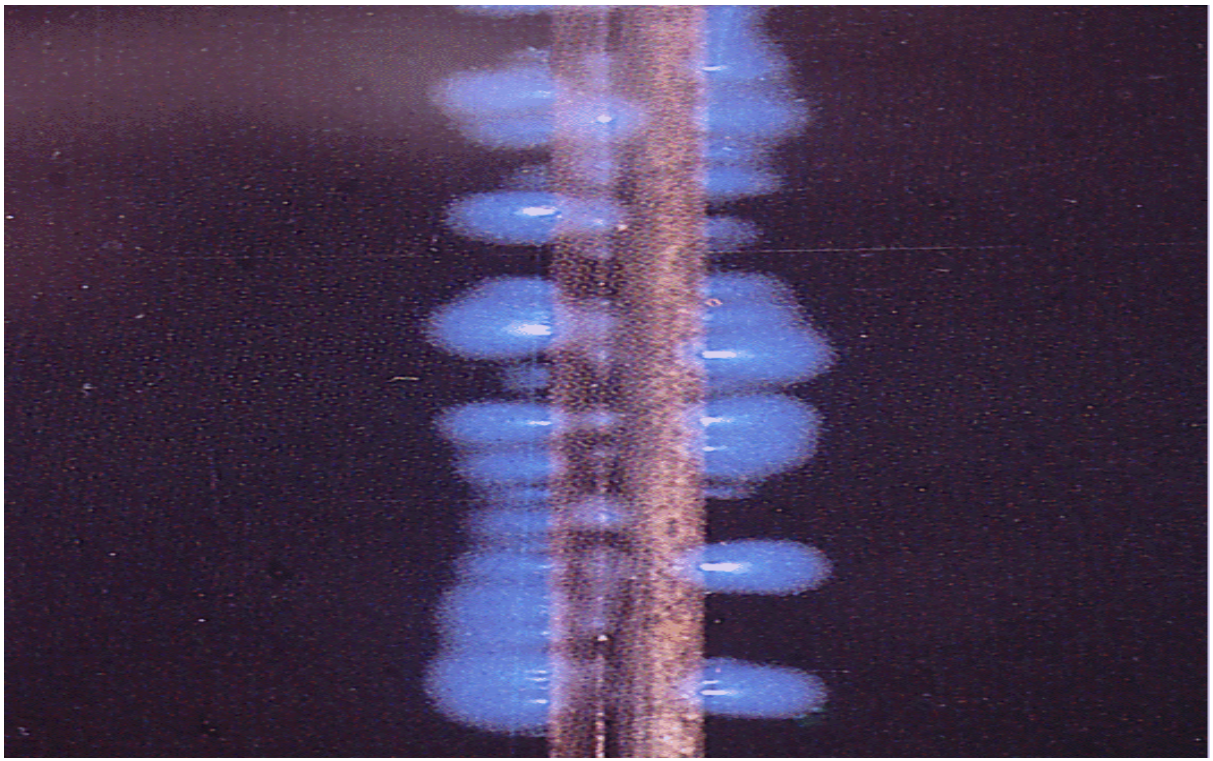
REINHOLD ENVIRONMENTAL Ltd.

2013 APC Round Table & Expo Presentation

July 8-9, 2013, in St. Louis, MO / Hosted by Ameren

O & M High Frequency TR Sets APC Conference 2013



By R. F. Ridgeway

SHEL-B Environmental Emissions Consulting, Inc.

Discussion Agenda

1. **General Overview:**
   - High Frequency TR Set Suppliers & Definitions
   - TR Set Power Processing, Technology (High Frequency vs. Convention)

2. **HF Technology Overview:**
   - Operational enhancements
   - Sizing
   - Harmonics

3. **Failures**
   - How to do a costs comparison
   - Root Causes & Remedy Actions
   - Maintenance Considerations

4. **Rapper Tuning**

5. **Summary**

High Frequency TR Sets Suppliers

- Alstom Power - SIR; Vaxjo, Sweden (USA Operations - Knoxville, TN)

- Applied Plasma Physics – ModuPower; Sandnes, Norway (USA Licensee Stock Equipment Company)

- NWL - PowerPlus; Bordentown, New Jersey

- Redkoh/Stein – Mid-frequency; Hillsborough, NJ

Definitions

Diode Bridge – Rectifies AC to DC

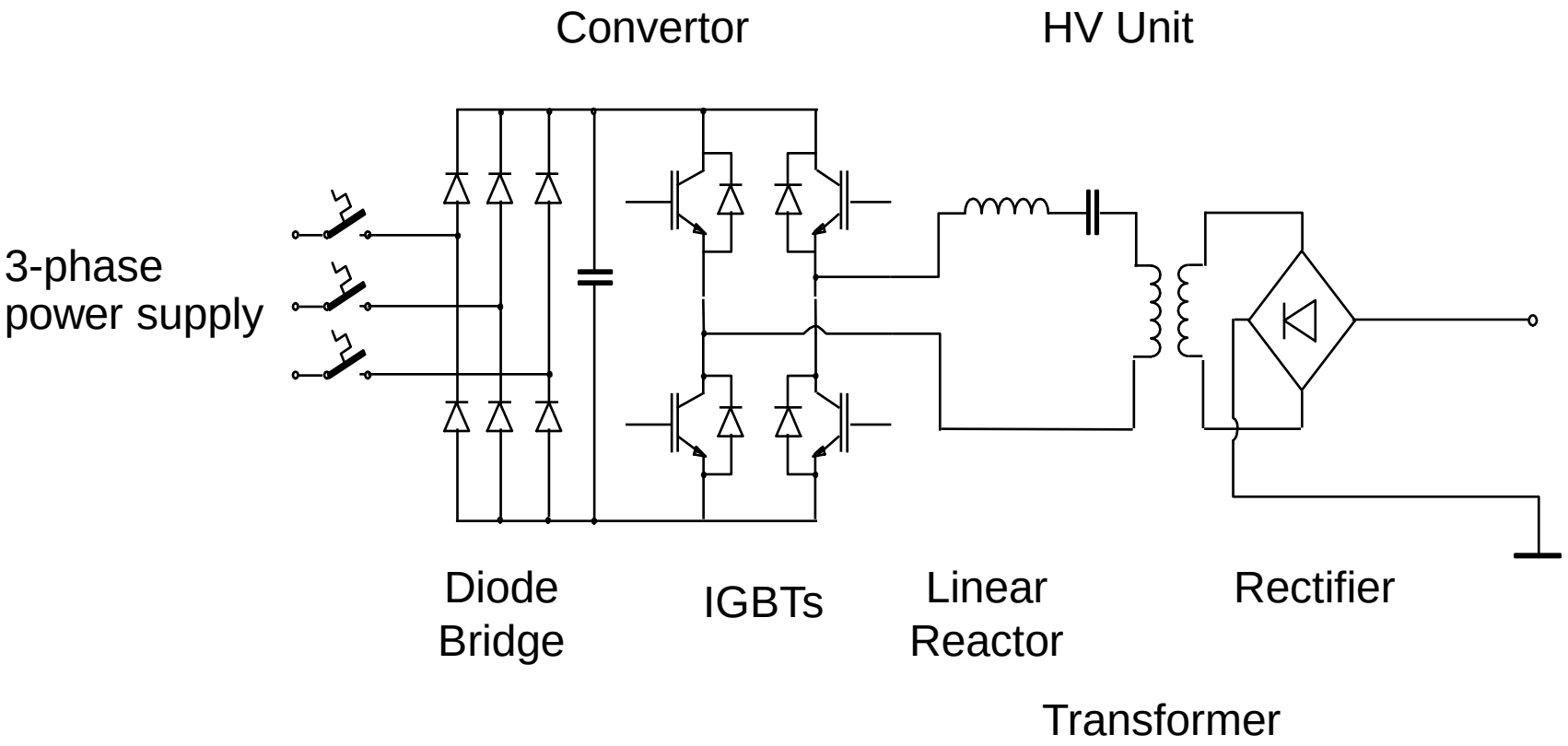
SCR – Silicon Controlled Rectifier

IGBT – Insulated Gate Bi-polar Transistor

HFTR Set – High Frequency Transformer Rectifier Set*

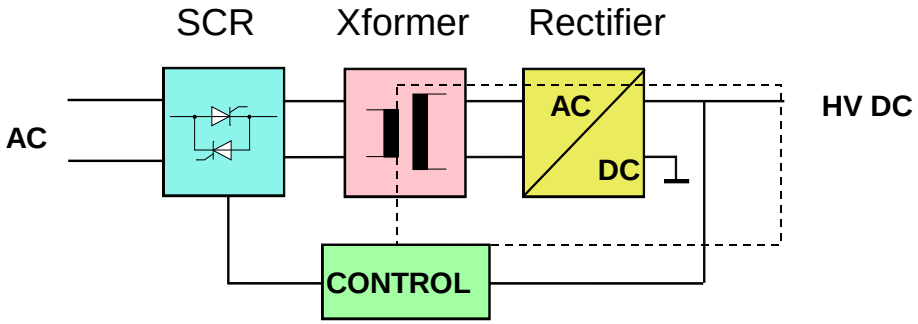
*Sometimes referred to a switch mode power supply (SMPS)

Power Processing (Principal Circuit Diagram)

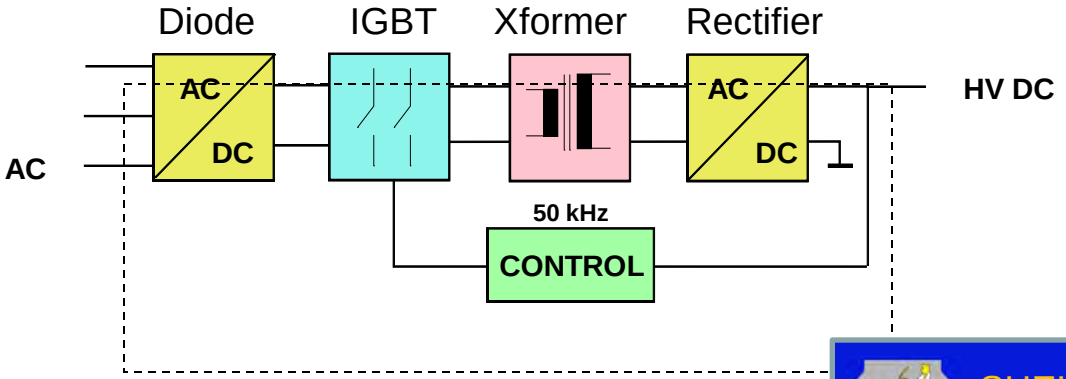


Power Processing

Conventional Frequency TR Set Power Processing



High Frequency TR Set Power Processing



On ESP Roof

TR Technology Comparison

Conventional

- Control
- SCR
- CLR
- TR Set

High Frequency

- HF TR Set
  - Control
  - Convertor
  - HV Unit

TR Technology Comparison

Conventional

- Switching by SCRs
- Requires Fire Suppression if Mineral Oil is Used
- Requires Control Calibrations to TR set
- Long life (30+ years)
- Modest O&M to TR set but electrical accessories and controls require O&M.
- *Standard performance*

High Frequency

- Switching by IGBTs
- Requires Fire Detection
- Generally “plug & play”, since Factory Calibrated
- More sophisticated technology & electronics
- Moderate life (may not achieve 30+ years)
- Require more PM (i.e., forced air or liquid cooling for filters, etc.)
- Compact package
- *Enhanced performance*
- **Grounding is imperative**

HF Technology Types

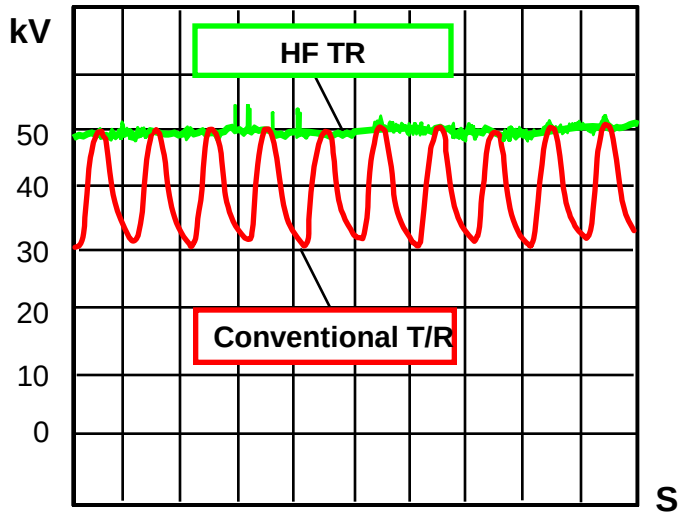
Roof Mounted

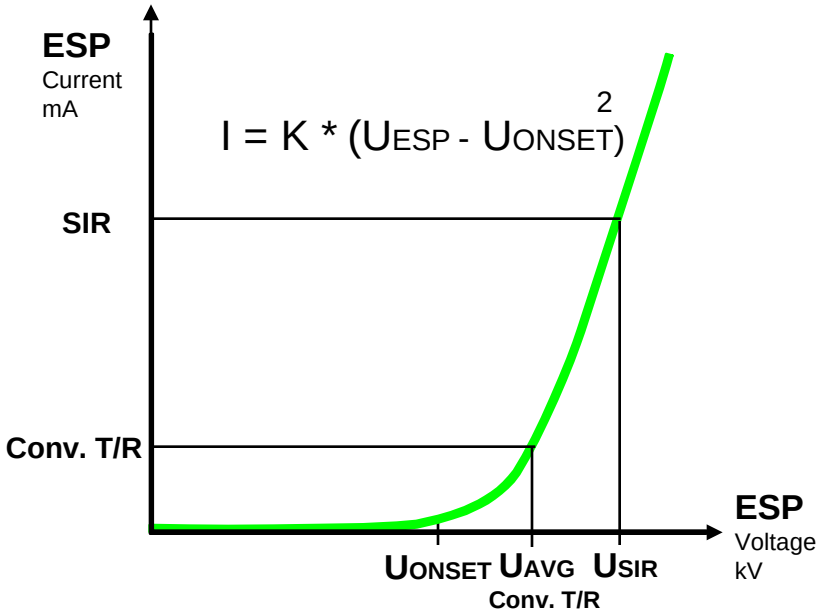
Remote Mounted

Operational Enhancements

- Higher Operating Field Voltage (10-15 KV)
- Faster Spark Response and Recovery

Field Voltage Increase





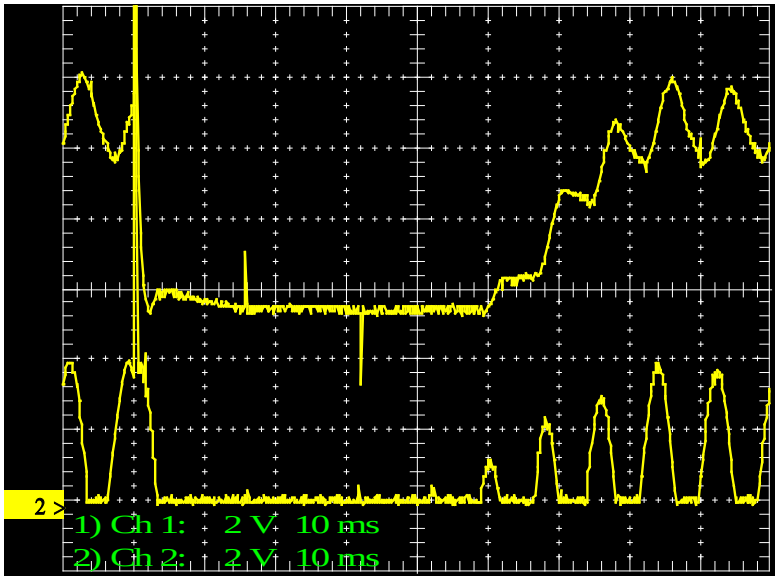
The HFTR set maintains a higher KV because in operates at the peak on the conventional TR set.

Spark Response

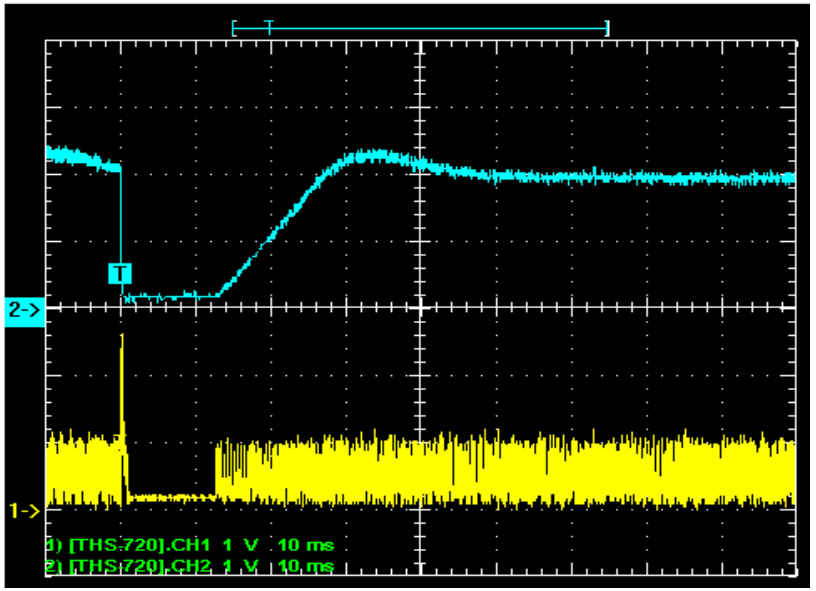
TR Set Waveform Comparison

Showing the HFTR's faster response to a spark

Conventional TR Set



High Frequency TR Set



Spark Response

TR Set Waveform Comparison

Showing the HFTR's faster response to a spark

Conventional TR Set

- Spark Quench:
  4 half cycles or 4 x 8.33 = 25.33 ms
- Set back 10%

High Frequency TR Set

- Spark Quench:
  4 ms
- Set back 3-5%

HF TR Set Sizing

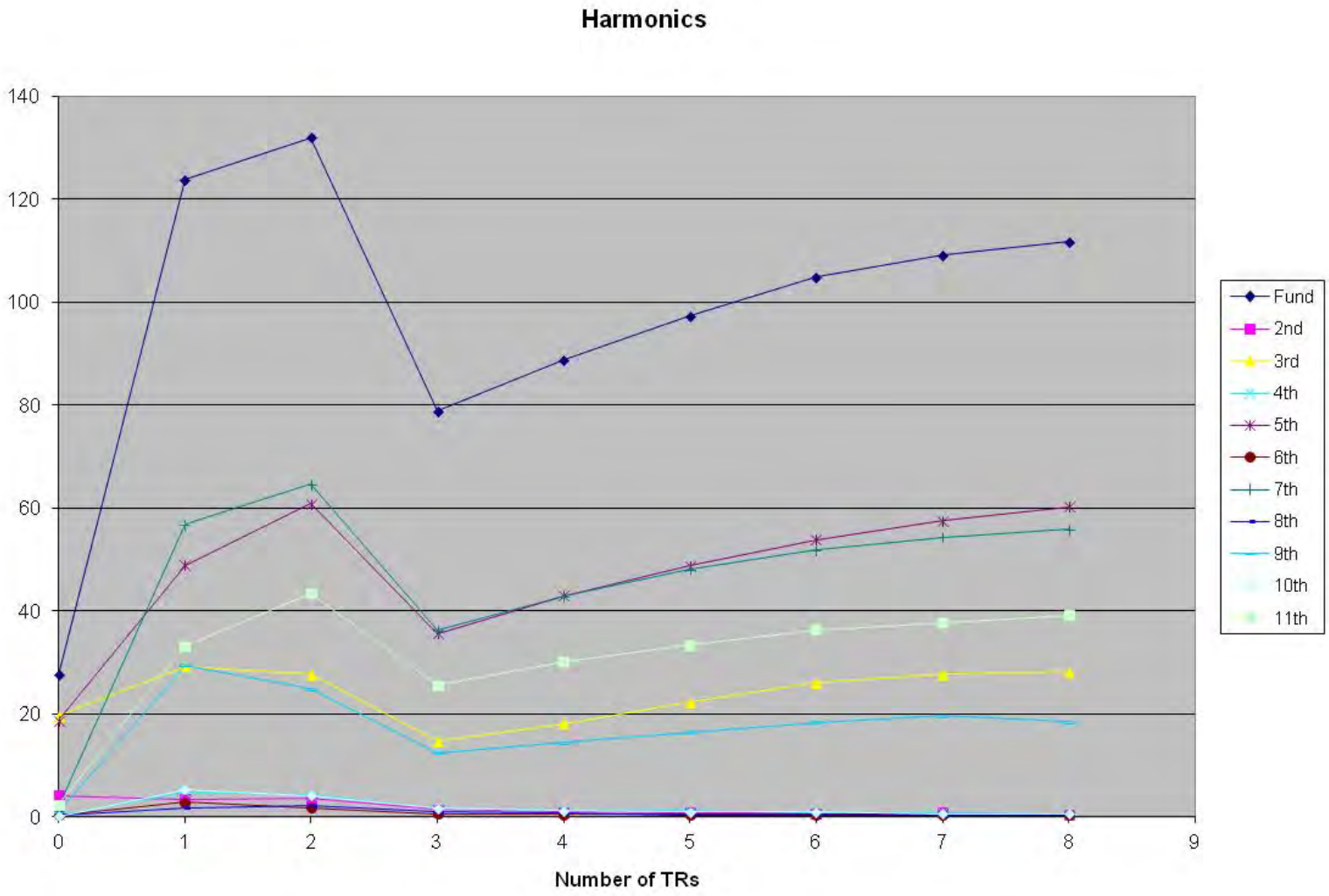
- Guides for Calculation HF TR set KV rating

  KV = 5 x (P-P Spacing) + 10
  or
  KV = 1.4 x (existing KV) - 7.5

- Guide for Calculating HF TR set mA rating

  mA = 0.00108 x (Sq-Ft of bus section) x (expected KV)

Harmonics on the Power Feed Can Be an Issue



Annual Cost Comparison (Conventional vs. HFTR)

Conventional TR Sets

- Total #TR set w/Controls
- AVC repair cost
- SCR cost
- Linear reactor cost
- TR set cost
- Sum Costs / # of TR sets

High Frequency TR Sets

- Total # of SIRs
- Control cost
- Convertor/Driver cost
- High voltage unit cost
- Sum costs / # of TR sets

Annual Cost Comparison (Conventional vs. HFTR)

Conventional TR Sets

- Total #TR set w/Controls = 132
- AVC repair cost
- SCR cost
- Linear reactor cost
- Sum Costs / # of TR sets

High Frequency TR Sets

- Total # of SIRs = 60
- Control cost
- Convertor/Driver cost
- High voltage unit cost
- Sum costs / # of TR sets

Root Cause of Failures

- Marginal IGBT's – More robust IGBT's are now available
- Counterfeit Components – Vendors are working to insure a controlled parts supply and have in-house testing of the components to verify they are to specifications.
- Contamination in PC boards manufacturing due to process changes – Specifications have been tightened to restore PCB integrity.
- Output bushing electrical stress failures – Redesigned bushing to reduce stresses.
- Elevated internal ground voltages – Proper grounding is essential to protect the IGBT and diode bridge.
- Heat stress – Due to the increased electronics which are now on the ESP deck heat is an issue. Although cooling systems have been improved, ash from casing leaks and coal from overhead conveyers can cause pluggage and restrict air flow.

Overheat Due to Ash Pluggage

- **Air Intake – Pluggage**

Plan Ahead for Maintenance

Convertors/Drivers are easier to change than the high voltage units.

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Be Aware of Obstacles

Make sure the design group watches out for:

•TR set pedestal & ground switch height can be too high resulting in access to the HF TR set controls.

•If TR set located on roofs with high winds, access doors may need prop rods.

•Rappers can blocking access doors.

•Overhead cable trays can limit HV unit replacements

Some Site Obstructions

Rappers Blocking Access Door

Overhead Cable Tray will Limit HV Unit Replacements

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Tuning the Rappers

Rapper programs will need to change!

•Turn off the rappers for a period of time to benchmark the percentage of your opacity which is due to rapper reentrainment.

•The target should be 10-20% of the base opacity w/o rapping.

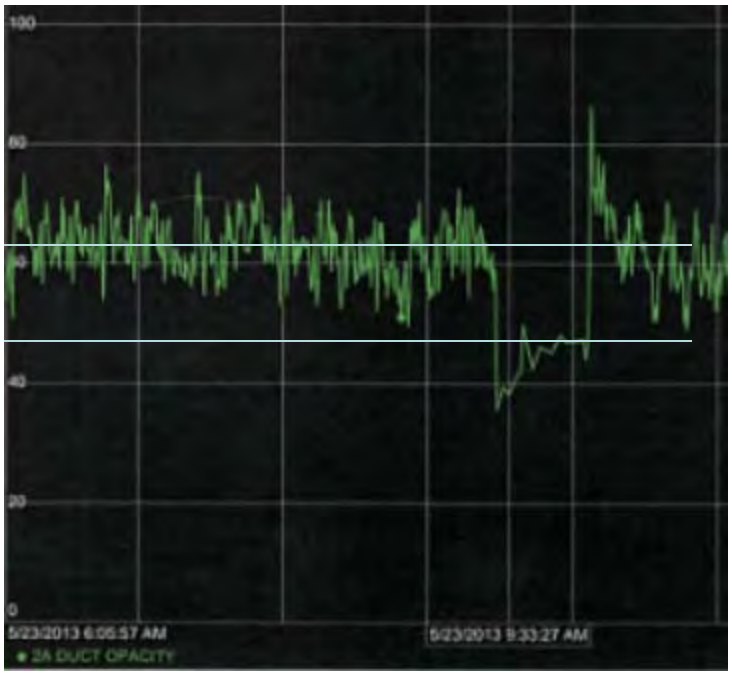
Example: if 12% is the base line

then target is 12+1.2 = 13.2 to 12+2.4 = 14.4%

•If the opacity percentage increase is too high, then slow rappers while observing changes in the V-I curves, total secondary current and the average secondary voltage .

•Tuning may take several days

Tuning the Rappers

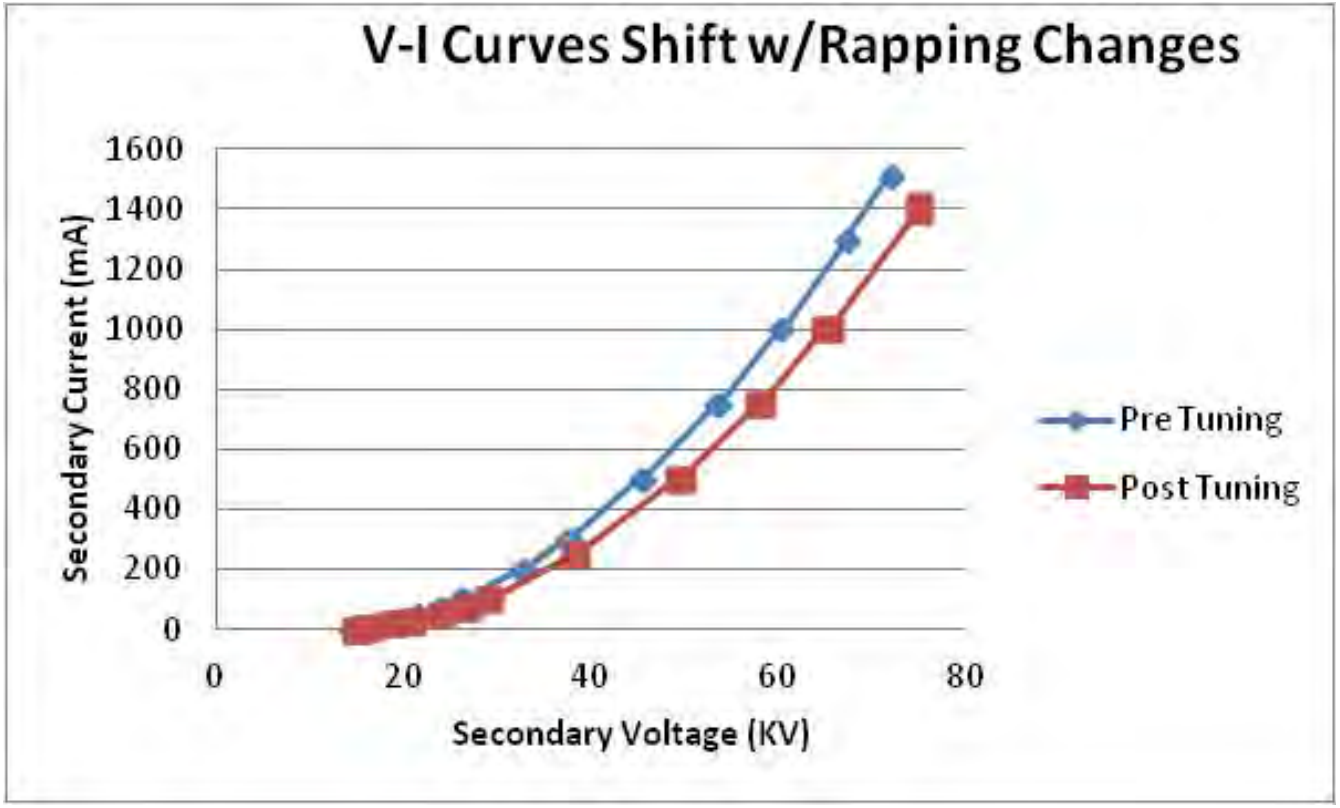


Baseline = 47%

Opacity w/rapping = 62%

15/47 = 32%

Monitor the V-I Curves



Summary

- The technology is now about 20 years old.
- High Frequency TR sets had a significant failure rate early on.
- OEM spare parts availability has been enhanced.
- Reliability has improved – but proper grounding and controlling temperatures are still an issue
- Give consideration to TR set maintenance when locating the sets. The set location could determine your selection of vendor.
- Although HFTR applications were generally on performance challenged ESP's, future applications will likely be part of a MATS strategy plan and replacement of TR sets at their end of life.

Questions