

REINHOLD ENVIRONMENTAL Ltd.



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Stein Industries Inc.

Engineered Electrical Apparatus & Systems



*Is there a “Best” Operating
Frequency Required for Switch
Mode Power Supplies*

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Paul Ford, Redkoh Industries – Hillsborough, NJ



The Answer Remains Contentious

- With so many “Opinions” on the subject, the best way to approach this question is really to look at the technology options and see where they benefit your plant.
- We suggest that the best frequency is the one that gives your plant the best value for your financial investment.
- The High Frequency SMPS manufacturers have presented vast amounts of information on their approach.
- We will present the Mid Frequency Case in this presentation.

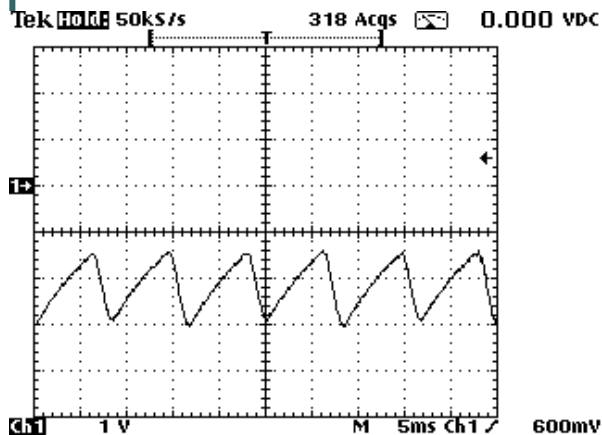
What is a Switch Mode Power Supply?

- A switch mode power supply uses IGBTs (Isolated Gate Bi-polar Transistor) to produce power at some frequency other than a standard line frequency of 50/60 Hz, where conventional SCRs (Silicon Controlled rectifiers) would suffice.
 - **Examples of these would be**
 - **100 Hz**
 - **400/500 Hz**
 - **> 10 kHz**
- These frequencies differ significantly, but all work towards a common goal in improving the performance of an ESP.

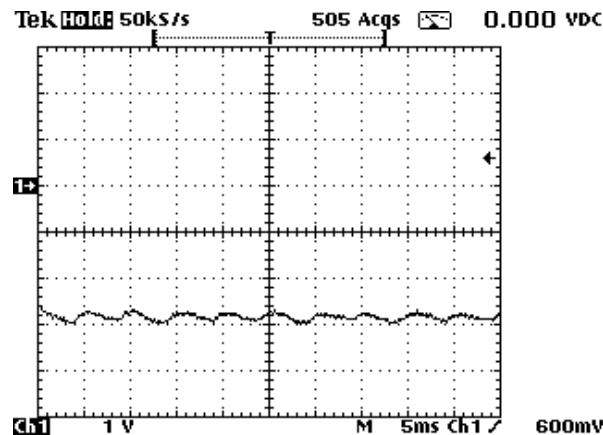
The Goals

- **Maximize the average voltage to the ESP, while minimizing the peak voltage.**
 - Reduce the peak to peak ripple of the secondary voltage supplied by the TR set to the ESP
- **Precipitators spark most frequently at the peak of the applied KV.**
 - Reducing the peak voltage while maintaining a high average voltage reduces the sparking within the ESP.
- **Reducing the frequency of sparking reduces the voltage “downtime” on the ESP**
 - Minimizing the downtime allows longer durations for the current in the ESP to build up.
- **Higher average precipitator voltage allows more time for current to flow keeping the power levels to the maximum.**
 - Higher power in the ESP promotes improved ESP collection efficiency.

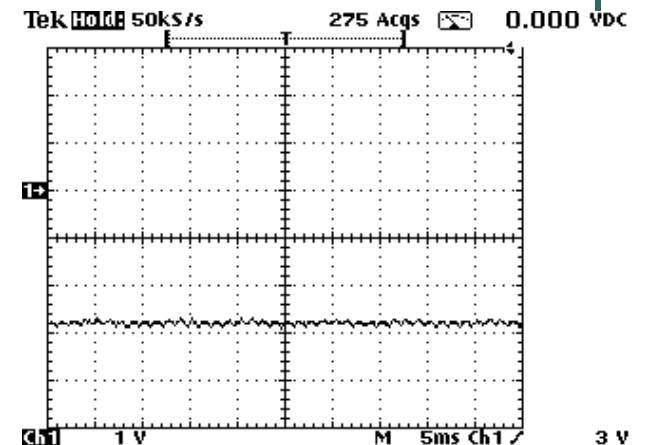
The Differing Techniques



60 Hertz – SCR
Energized



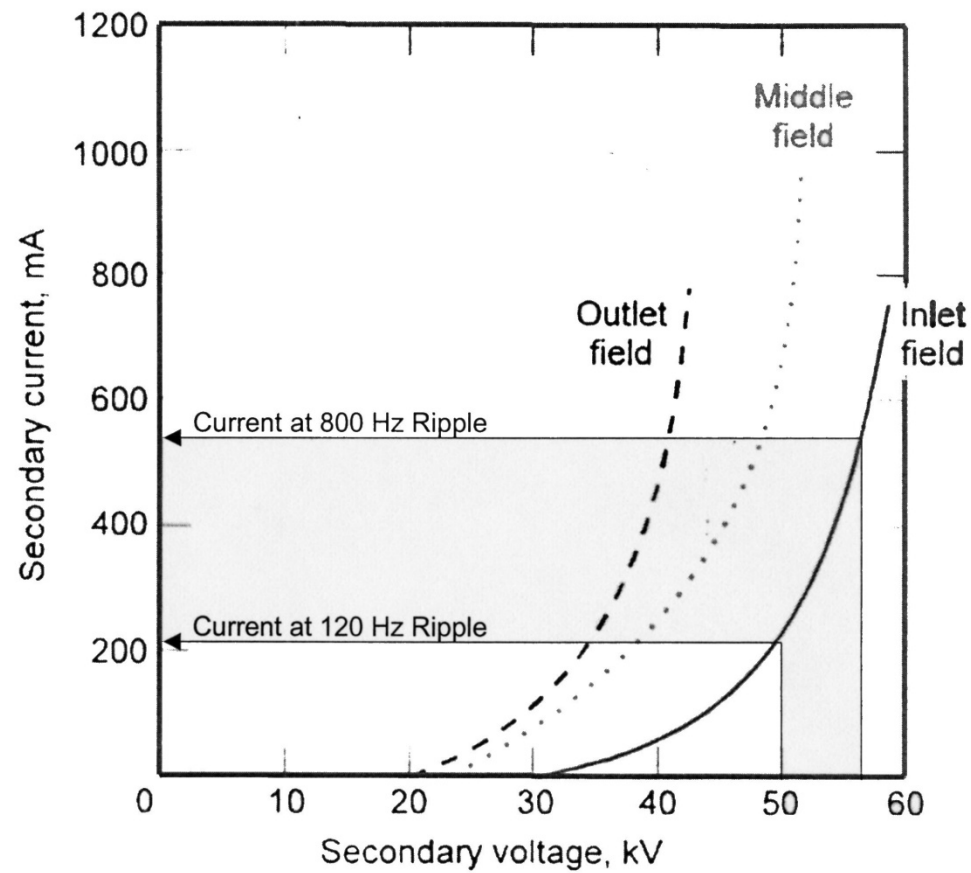
100 Hertz – IGBT
Energized



400 Hertz – IGBT
Energized

The ESP load for the above waveforms is identical.
Only the method of energization differs

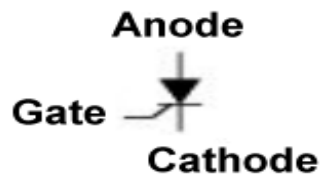
The Results



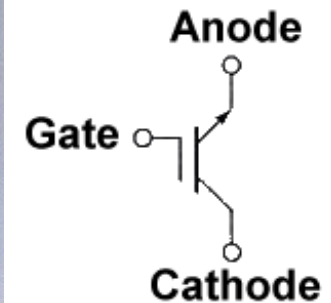
Switch Mode Control Responses

- On an SCR control current continues to flow into the spark or arc up until at least the end of the half cycle (8.3 milliseconds).
 - SCR's are turned on by the controller
 - They cannot be turned off, they must wait for the current to cease flowing and then they turn themselves off.
- On a switch mode power supply, and this is independent of the frequency of energization:
 - Power is removed by the controller as soon as the spark or arc is detected,
 - The IGBT's are turned off interrupting the flow of current into the spark or arc (20 microseconds).

Silicon Controlled Rectifier (Thyristor) vs. Isolated Gate Bipolar Transistor



**Turns-on only every 8.3 ms.
Turns off at 'zero crossing'
(SCR - 60 Hz Device)**



**Turns On and Off on command
(IGBT)**

The Control Cabinets



**Mid Frequency 400 Hz Power
Supply Control Cabinet**



**Mid Frequency 400Hz Power
Supply Control Cabinet**

The Power Supplies

- The MFPS is made up of:
 - The Controller.
 - The Inverter.
 - The Transformer Rectifier.
- A great deal of attention is paid to the to the controller and the inverter and while supremely important:
- Very little attention is paid to the Transformer Rectifier.
- The TR is a significant source of performance related cost in the planning process.
- So How do we adapt 40 years of good solid transformer rectifier design to ESP “switch mode power supplies”.
- Where does this fit in the evaluation of such a system.

The Transformer Rectifiers



The Conventional (60Hz) TR set operating at 60 Hz

- **Benefits**

- Plenty of power.
- A lifetime of reliability.
- Conservative and proven designs.
- A wealth of knowledge and support.
- A huge installed base.
- Numerous companies manufacturing and re-building.
- Known and reliable control and switching topologies.
- Plant personnel supported.

- **Limitations**

- 120Hz ESP “ripple”.
- Contribute to poor power factor.

The Conventional (60Hz) TR set operating at 400Hz

- **Benefits**

- Reduced ESP “ripple” provides improvements in ESP performance.
- A lifetime of reliability.
- Conservative designs
- A wealth of knowledge and support.
- A huge installed base.
- Numerous companies manufacturing and re-building.
- Known and reliable control and switching topologies.
- Plant personnel supported.

- **Limitations**

- Best location is where ESP power is below 50% of design
- CLR needs upgrading to match 400 Hz impedance.

The Conventional TR Set at 100 Hz modulated with 1.6 kHz

- **Benefits**

- Reduced ESP “ripple” provides improvements in ESP performance.
- A lifetime of reliability.
- Conservative designs
- A wealth of knowledge and support.
- A huge installed base.
- Numerous companies manufacturing and re-building.
- Known and reliable control and switching topologies.
- Plant personnel supported.
- Uses the same CLR
- No de-rating of the TR set

- **Limitations**

- Slightly more ripple than at 400 Hz.

The 400Hz TR Set

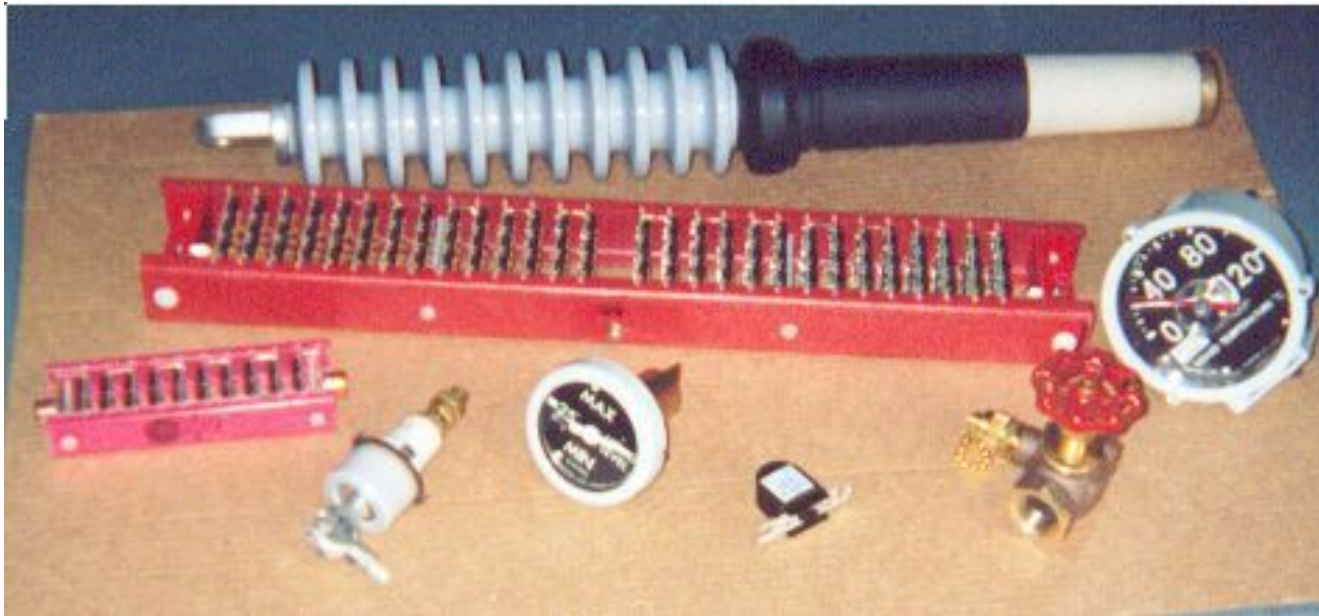
- **Benefits**

- **Possess all the benefits of the Transformers listed above**
- **Significantly higher power capabilities as a result of conventional design techniques**

- **Limitations**

- **TR power is not limited by TR design, but rather by available IGBT**

The 400Hz TR Set



*Recognize these?
You should do.... You are already using
them!*

Closing Arguments

- **Mid Frequency Switch Mode Power Supplies Provide:**
 - Suitable waveform to the TR set in order to minimize ESP Ripple.
 - Increased average voltage to the ESP.
 - Increased current flow to the ESP.
 - Fast response times to events occurring in both the ESP and Power system.
 - Possess all the benefits of the tried and trusted transformer rectifier design
 - Significantly high power capabilities.
 - Improvement in power factor
 - Reuse of existing cabling, control rooms and Mechanical TR footprints
 - No Duct work modifications
 - Provides a solution rather than a one fits all product?
- **So Really.....The best frequency.....What do you think?**