

# Worldwide Pollution Control Association

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

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# *The Answer Remains Contentious*

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- 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?*

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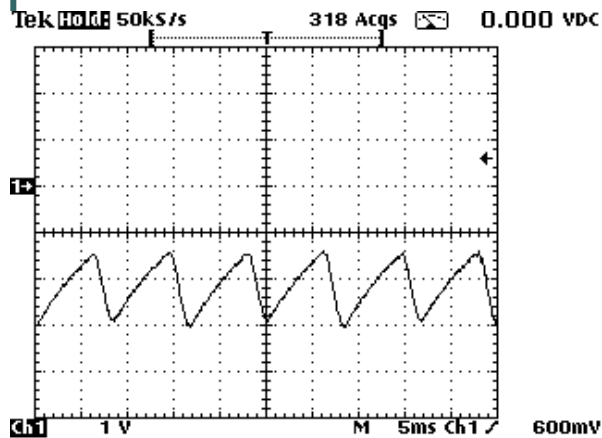
- A switch mode power supply uses IGBTs (Isolated Gate Bi-polar Transistor) to produce power at some frequency other than a standard line frequency of 50/60 Hz, where conventional SCRs (Silicon Controlled rectifiers) would suffice.
  - **Examples of these would be**
  - **100 Hz**
  - **400/500 Hz**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

# *The Goals*

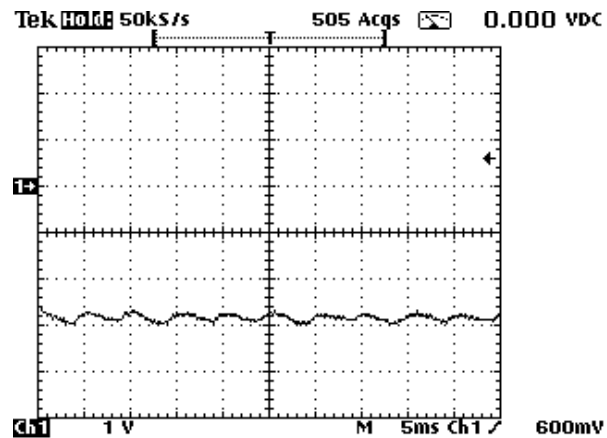
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- **Maximize the average voltage to the ESP, while minimizing the peak voltage.**
  - Reduce the peak to peak ripple of the secondary voltage supplied by the TR set to the ESP
- **Precipitators spark most frequently at the peak of the applied KV.**
  - 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.

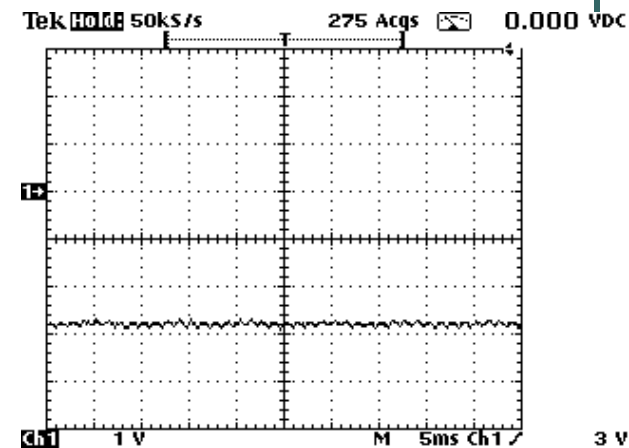
# The Differing Techniques



60 Hertz – SCR  
Energized



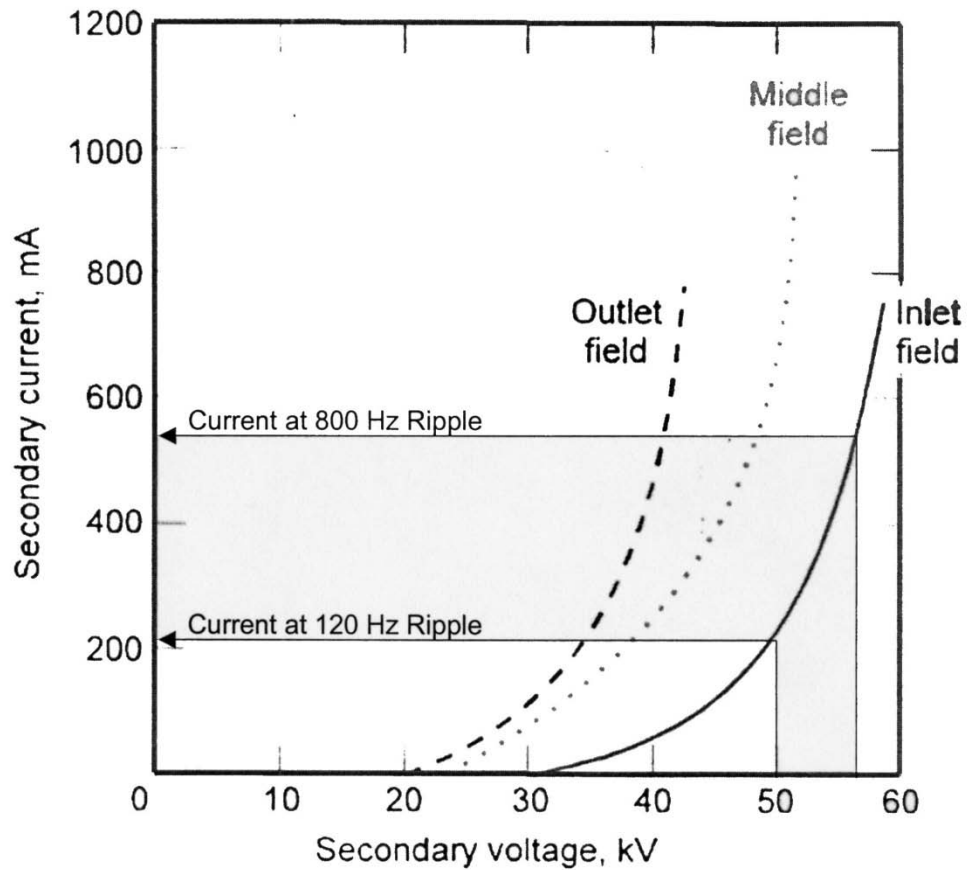
100 Hertz – IGBT  
Energized



400 Hertz – IGBT  
Energized

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

# The Results

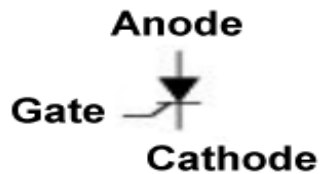


# *Switch Mode Control Responses*

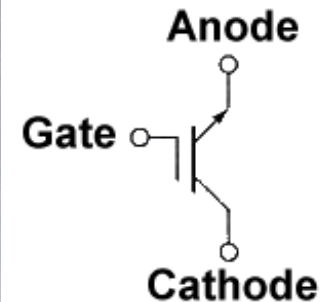
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- On an SCR control current continues to flow into the spark or arc up until at least the end of the half cycle (8.3 milliseconds).
  - SCR's are turned on by the controller
  - They cannot be turned off, they must wait for the current to cease flowing 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*

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- 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*

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- **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*

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- **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*

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- **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*

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- **Benefits**

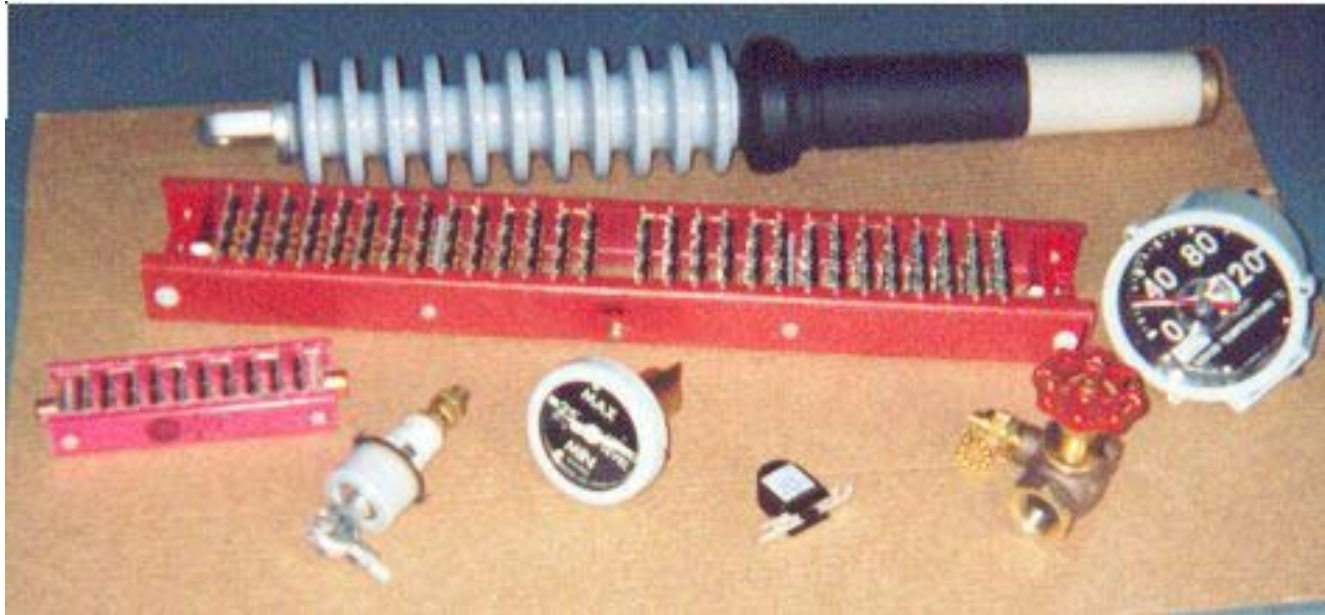
- Possess all the benefits of the Transformers listed above
- Significantly higher power capabilities as a result of conventional design techniques

- **Limitations**

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

# *The 400Hz TR Set*

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

# *Closing Arguments*

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- **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?**