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Is there a "Best" Operating Frequency Required for Switch Mode Power Supplies

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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.

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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.**

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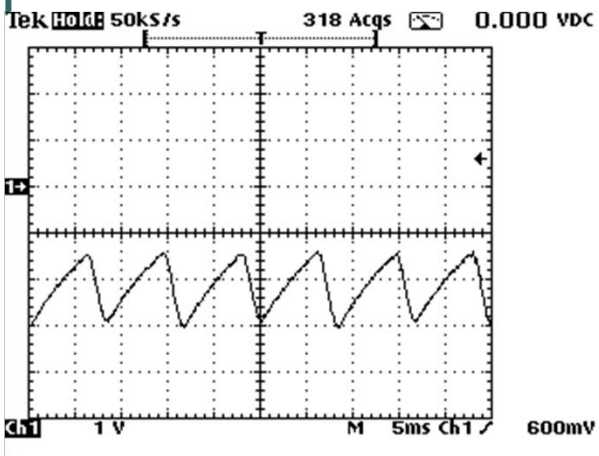
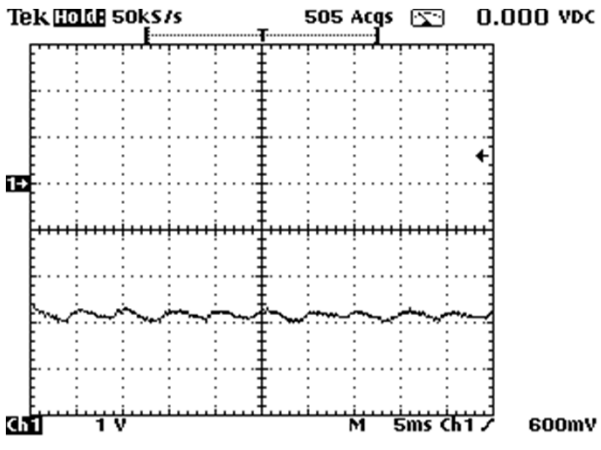
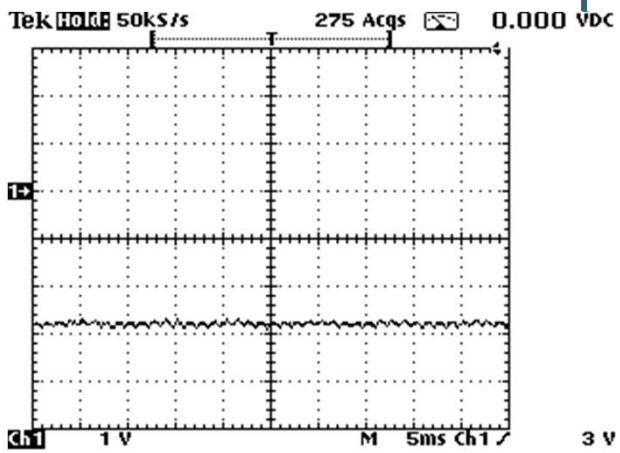
The Differing Techniques



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

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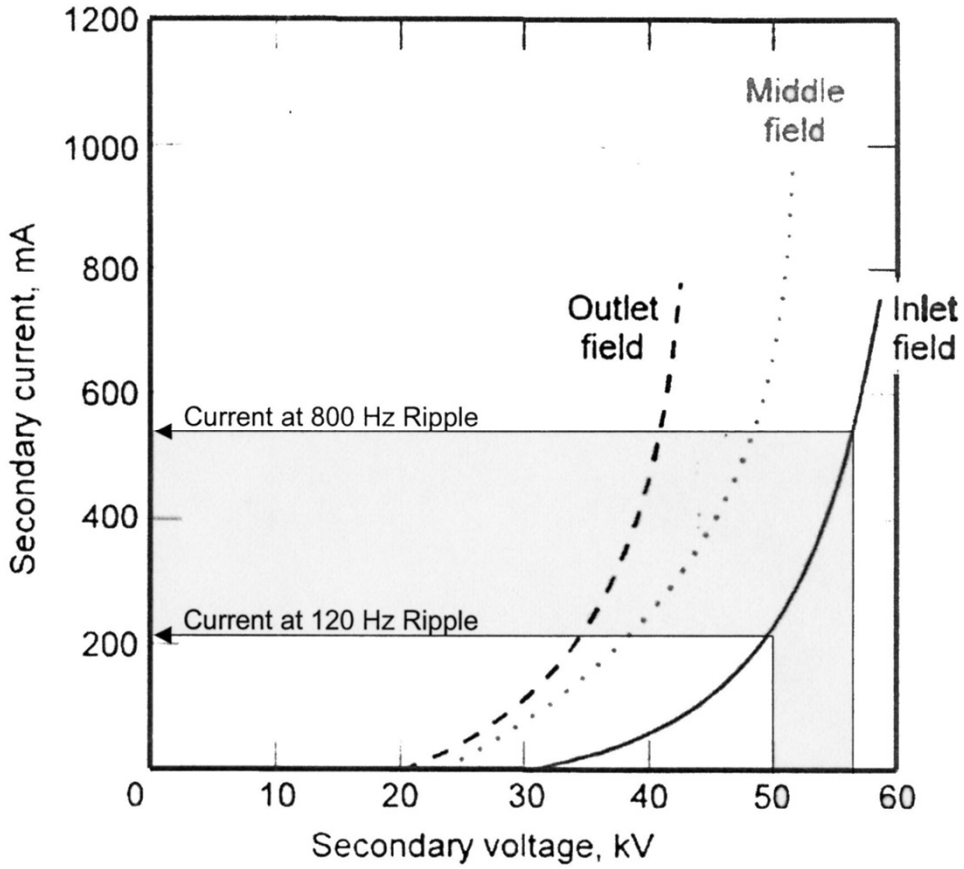
The Results



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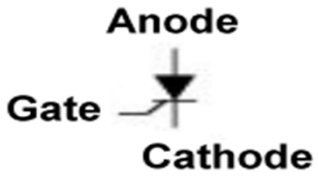
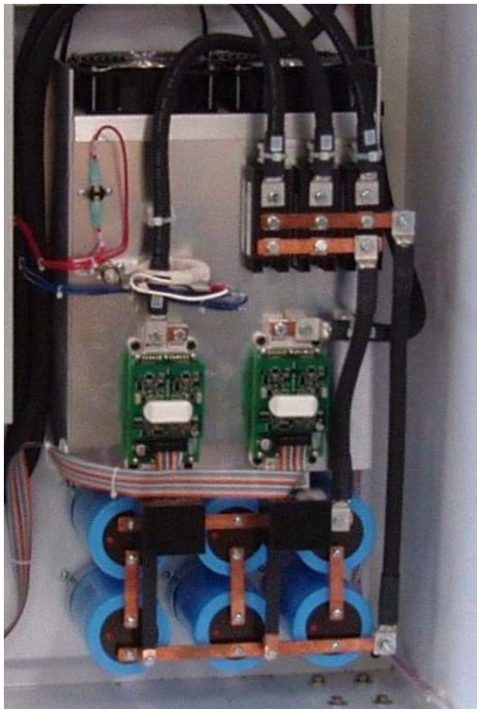
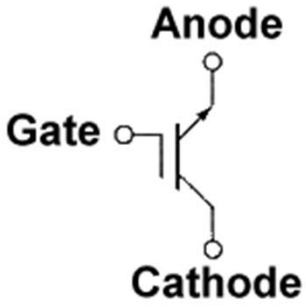
Switch Mode Control Responses

- 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)

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The Control Cabinets

Mid Frequency 400 Hz Power Supply Control Cabinet

Mid Frequency 400Hz Power Supply Control Cabinet

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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.

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The Transformer Rectifiers

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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.**

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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.**

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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.**

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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**

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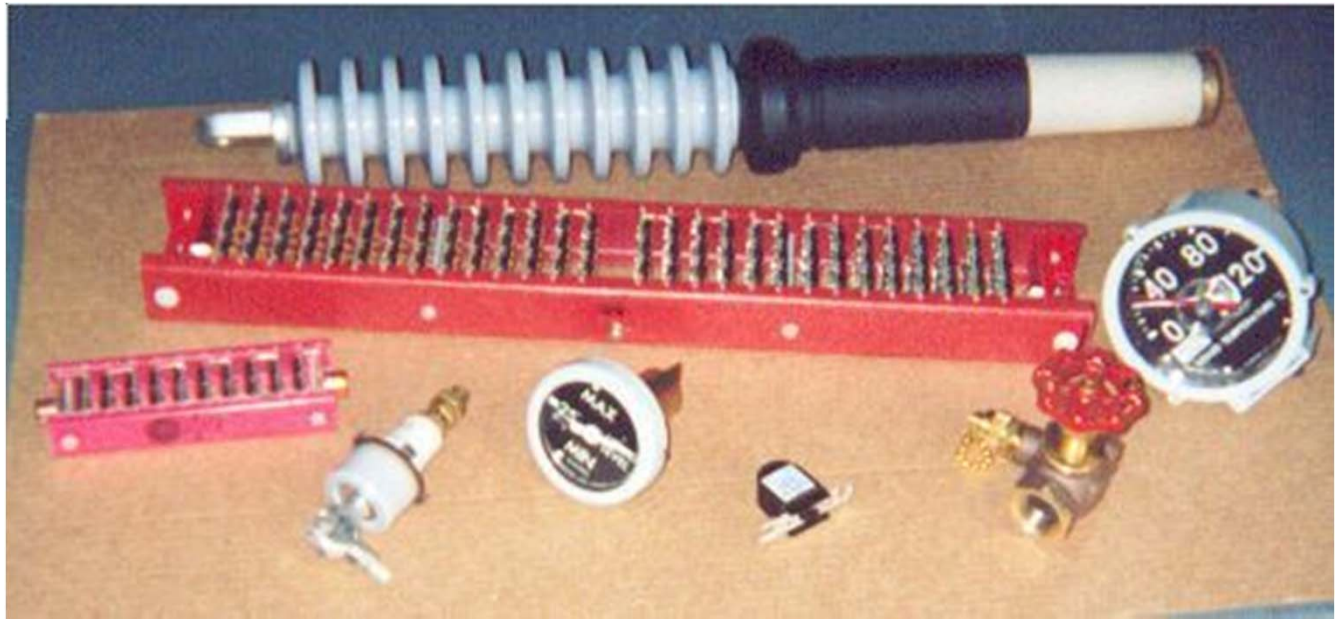
The 400Hz TR Set



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

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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?**

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