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.
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

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 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?