Application Notes for X-Ray Generators

AN-03: Floating Filament X-Ray Generators and the Possible Problems That Long High Voltage Cables Can Produce

Background:
Spellman has been making X-Ray generators for over 3 decades. Most fall into three basic categories:
- Ground Referenced Filamentary Control
- Floating Filamentary Control
- Bipolar Output Filamentary Control

Ground Referenced Filament X-Ray Generators Type:
Ground Referenced Filamentary Control X-Ray generators include: XMPG, XLG, FF, DXM, MNX, uX, uXHP, VMX and the PMX. These X-Ray generators typically have a positive output voltage with respect to ground. The filament is DC and is ground referenced. The temperature (amps) of the filament, the voltage potential (kV) and exposure time will determine the output X-Ray imaging characteristics. Since the filament is at ground and DC, implementation of filamentary control for this X-Ray generator is fairly straight forward and simple.

Floating Filament X-Ray Generator Type:
Floating Filamentary X-Ray Generators include XMPF, DF, XRF, DXM, DXM100, XLF, DXB, and MFX . These “floating filament” X-Ray generators are different…their filament power supplies are referenced to the negative cathode output voltage. That means that the filament power supply must be controllable (using ground referenced programming and feedback signals) while being connected to the main high voltage output, in some cases at -160kV or greater. Implementing floating filament X-Ray generators are more complicated.

Bipolar Output X-Ray Generator Type:
Bipolar Output X-Ray generators utilize a floating filament circuit (think Floating Filament X-Ray Generator) but instead of just leaving the anode at ground, it is elevating it at the same but opposite polarity potential of the cathode. This effectively doubles the voltage across the X-Ray tube, allowing greater output power. The implementation functions like a standard floating filament X-Ray generator, with all the same engineering complexities.

Ground Referenced Filament Driver Circuits:
Ground Referenced filament circuits (X-Ray generators with a positive output polarity) are for the most part easier to design and fabricate. The filament supply is typically a small 0 to 5 amp @ 10Vdc power supply. This is relatively simple to implement and design because its ground referenced, and it is DC. Because the filament output is DC, driving long high voltage cable lengths tend to be more forgiving. If there is adequate compliance voltage designed in the DC filament driver to drive the long cable, all should be good. In general, ground referenced DC filament circuits are just simpler, from a design and implementation perspective.

Floating Filament Driver Circuits:
Floating Filament Driver Circuits are more complicated from an Engineering perspective because they must be connected (referenced) to the negative high voltage output potential of the cathode of the X-Ray tube. Isolation voltage requirements are for -50kV, -100kV, -160kV or more. Isolation transformers are run at high frequency AC, since transformers only function with

AC waveforms. Filament circuits operate in current mode, so obtaining a sample of the actual filament current is easy using a current sense transformer. Here utilizing AC for the filament output simplifies the isolation and sensing requirements of the filament circuit. Typically, the operating frequency for the floating filament circuits are approximately 30 to 40 kilohertz. High enough in frequency to be inaudible and to also high enough to keep the size of the filament isolation transformer magnetics and filament driver circuitry to a reasonable size.

The Problems with Long High Voltage Cables Using an AC Filament

Using high frequency AC for a floating filament X-Ray tube application makes some of the design tasks easier, but there is one potential drawback using this technique. The high voltage cable becomes part of the “tuned resonant circuit” of the AC filament driver and excessive high voltage cable lengths can result in some fundamental operational problems. The standard negative output voltage DXM sold with an AC filament is calibrated with a 10 foot long high voltage cable. Excessively long high voltage cables can have so much inductance the filament driver circuit may not have adequate voltage compliance to drive the long high voltage cables, causing problems operating the X-Ray tube. Basically, all the AC high frequency voltage gets dropped across the long high voltage cable leaving inadequate capability to drive the X-Ray tube filament properly. AC filament circuits are not designed to drive long high voltage cables.

Conclusion/Suggestion:

When working with X-Ray generators be it DC or AC filaments, use the sensible engineering approach to try to keep the high voltage cable (or filament cable) as short as reasonably possible.