

Rad-X Medical Power Filtration System® (Rad-X Filter) Installation Report

BACKGROUND

Applied Power Quality Solutions (APQS) was engaged to install a Rad-X Filter on a newly installed TomoTherapy Hi Art system. As a normal part of the startup process, APQS records electrical conditions before and after filter activation. For the purpose of this work, APQS uses a Dranetz/BMI, Model 8800, 8-channel power disturbance analyzer and a Summit Technology, Model PS 4000 with spectrum analyses module.

Pre Filter Activation

Figure 1 illustrates initial conditions with the TomoTherapy system in idle mode and the Rad-X Filter deactivated. High frequency noise levels were as high as 6.0 volts peak to peak (Vpp). Ideally, this level should be maintained below 0.5 Vpp. **Figure 2** was recorded with the TomoTherapy system in operation and the Rad-X Filter deactivated. High frequency noise is even higher at 6.9 Vpp and thousands of low-level voltage impulses were recorded.

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HEAT-SENN TOMO Jun 15, 2006
STATUS REPORT 10:28 AM
PH A-NEUT (Voltage Channel 1)
Voltage: 278.7 Urms
Frequency: 60.0 Hz
High freq noise: 5.9 Vpp
PH B-NEUT (Voltage Channel 2)
Voltage: 279.4 Urms
Frequency: 60.0 Hz
High freq noise: 6.0 Vpp
PH C-NEUT (Voltage Channel 3)
Voltage: 278.8 Urms
Frequency: 60.0 Hz
High freq noise: 5.5 Vpp
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Figure 1

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██████████ TOMO Jun 15, 2006
STRIP CHART REPORT From 10:00 AM To 11:00 AM 11:00 AM
PH A-NEUT (Channel 1)
Voltage: 276.7 Urms min: 280.2 Urms max
Current: 6.0 Arms min: 15.4 Arms max
Noise: 6.1 Vpp min: 6.8 Vpp max
Frequency: 59.9 Hz min: 60.0 Hz max
Impulses: 1366 counted: 55 Vpk max
PH B-NEUT (Channel 2)
Voltage: 278.1 Urms min: 280.6 Urms max
Noise: 6.2 Vpp min: 6.9 Vpp max
Frequency: 59.9 Hz min: 60.0 Hz max
Impulses: 1208 counted: 27 Vpk max
PH C-NEUT (Channel 3)
Voltage: 277.1 Urms min: 279.6 Urms max
Noise: 5.5 Vpp min: 6.6 Vpp max
Frequency: 59.9 Hz min: 60.0 Hz max
Impulses: 685 counted: 68 Vpk max
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Figure 2

Figures 3-5 are 1-hour time graphs. They are presented vertically in order to illustrate the time relationship between the TomoTherapy system operation (figure 3), high frequency electrical noise (figure 4), and low amplitude voltage impulses (figure 5). The red arrows point out the fact that as current usage increased, high frequency noise and voltage impulses were generated.

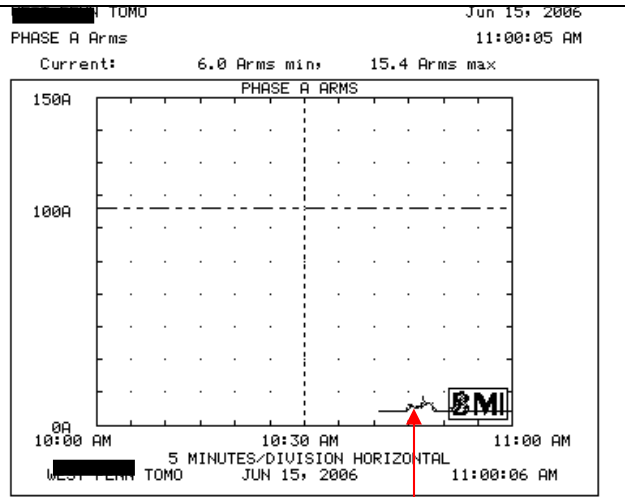


Figure 3

Figure 4 illustrates high frequency electrical noise between 3kHz and 1MHz. The blue arrow points to where high frequency noise levels should be and the green arrow points to where they actually were recorded.

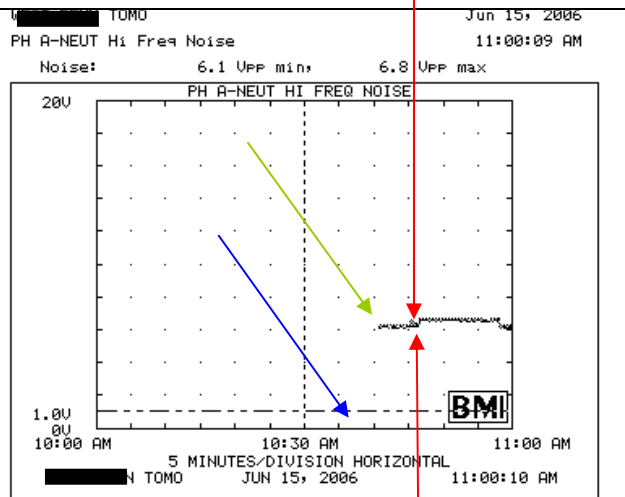


Figure 4

Figure 5 illustrates voltage impulses recorded between phase A and neutral. With close examination, we observe that some of the voltage impulses in figure 5 are associated with TomoTherapy system operation, while others are not. The indication is that the voltage disturbances are being generated by the TomoTherapy operation itself, as well as by sources that are outside of the TomoTherapy system operation. This is referred to as **line and load generated disturbances**.

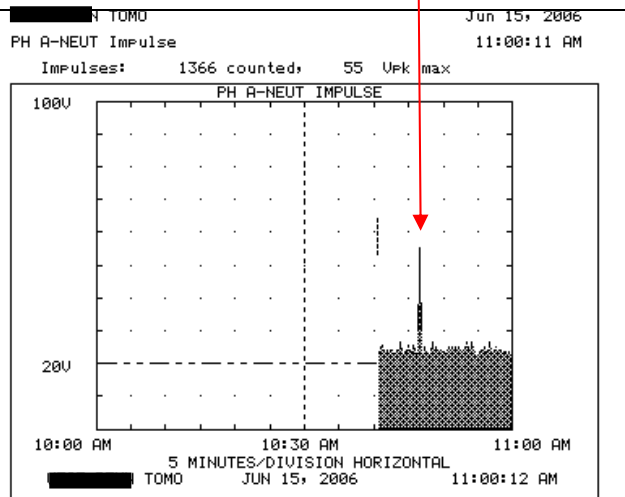


Figure 5

Figures 6-8 are spectrum analyses graphs recorded with the Rad-X Filter deactivated. Black = voltage; blue = current.

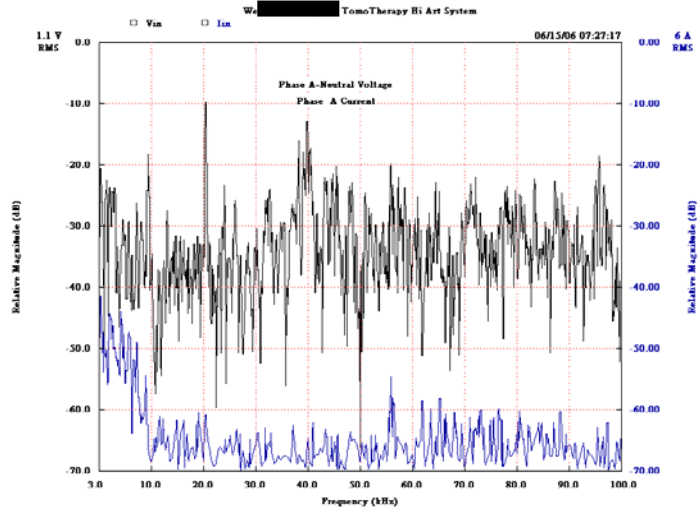


Figure 6

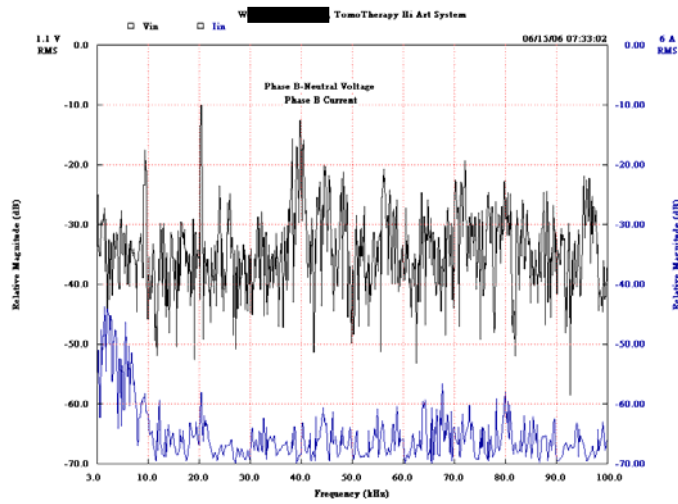


Figure 7

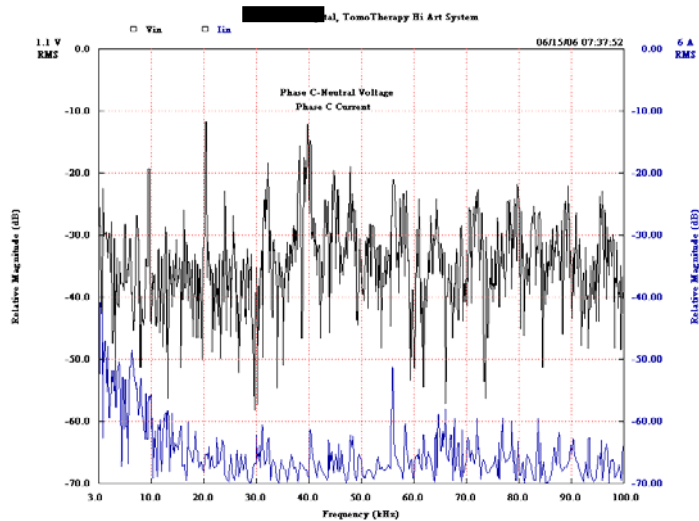


Figure 8

Post Filter Activation

Figure 9 illustrates initial conditions with the TomoTherapy system in idle mode and the Rad-X Filter activated. High frequency noise levels are dramatically reduced to a maximum of 0.3 Vpp. **Figure 10** was recorded with the TomoTherapy system in operation and the Rad-X Filter activated. High frequency noise levels remained low and no voltage impulses were recorded.

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██████████ TOMO P1
STATUS REPORT

PH A-NEUT (Voltage Channel 1)
Voltage:      281.8 Urms
Frequency:    60.0 Hz
High freq noise: 0.2 Vpp

PH B-NEUT (Voltage Channel 2)
Voltage:      281.9 Urms
Frequency:    60.0 Hz
High freq noise: 0.3 Vpp

PH C-NEUT (Voltage Channel 3)
Voltage:      281.4 Urms
Frequency:    60.0 Hz
High freq noise: 0.2 Vpp
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Figure 9

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Jun 15, 2006 ██████████ TOMO P1
2:07 PM STRIP CHART REPORT
From 2:00 PM To 3:00 PM

PH A-NEUT (Channel 1)
Voltage:      280.7 Urms min, 282.7 Urms max
Current:      5.8 Arms min, 15.1 Arms max
Noise:        0.2 Vpp min, 0.2 Vpp max
Frequency:    59.9 Hz min, 60.0 Hz max
Impulses:     0 counted

PH B-NEUT (Channel 2)
Voltage:      280.6 Urms min, 282.6 Urms max
Noise:        0.3 Vpp min, 0.3 Vpp max
Frequency:    59.9 Hz min, 60.0 Hz max
Impulses:     0 counted

PH C-NEUT (Channel 3)
Voltage:      279.6 Urms min, 282.1 Urms max
Noise:        0.2 Vpp min, 0.3 Vpp max
Frequency:    59.9 Hz min, 60.0 Hz max
Impulses:     0 counted
```

Figure 10

Figures 11-13 are spectrum analyses graphs recorded with the Rad-X Filter activated. High frequency noise is significantly attenuated. Black = voltage; blue = current.

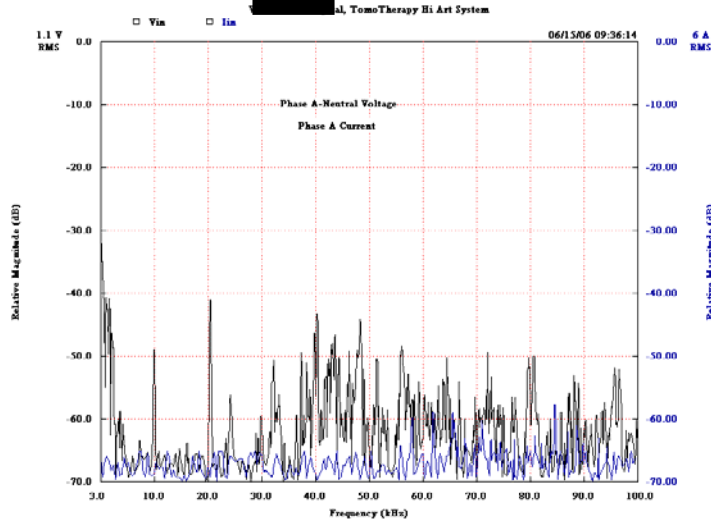


Figure 11

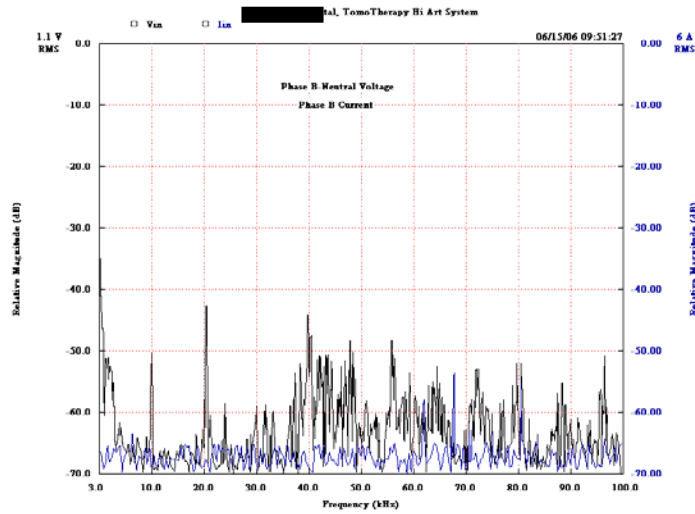


Figure 12

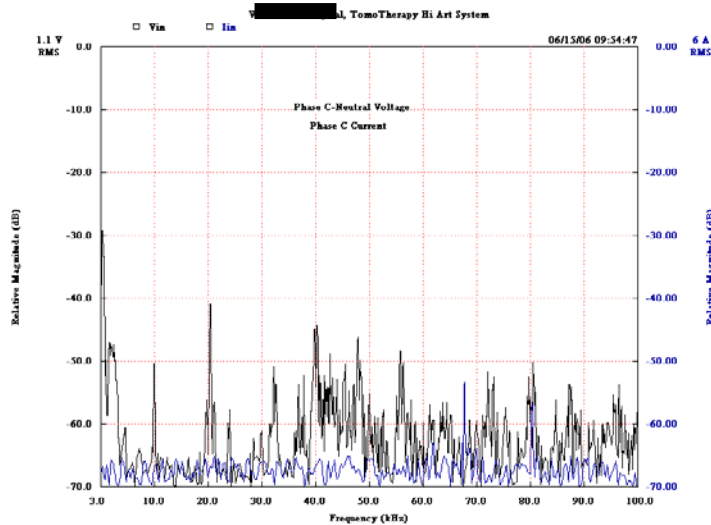
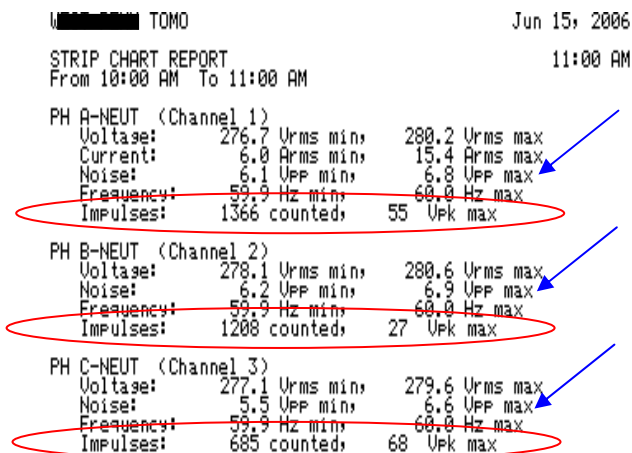


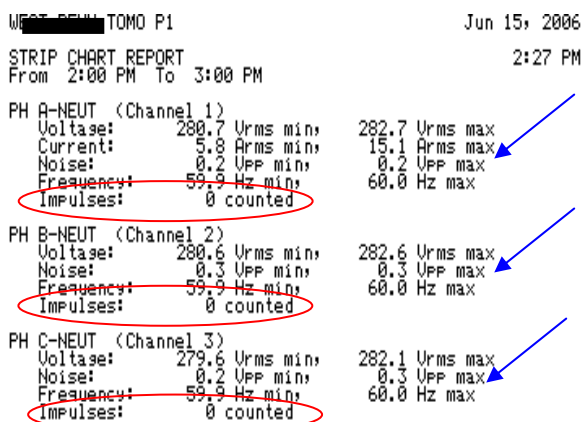
Figure 13

CONCLUSIONS

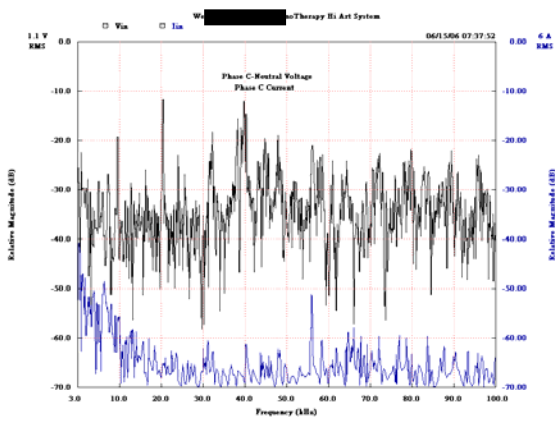
The pre Rad-X Filter activation graphs below illustrate that the electrical environment appeared more like a welding shop than a state of the art radiation oncology system installation. The post Rad-X Filter activation graphs illustrate an electrical environment in which the TomoTherapy Hi Art system can operate at its full potential.



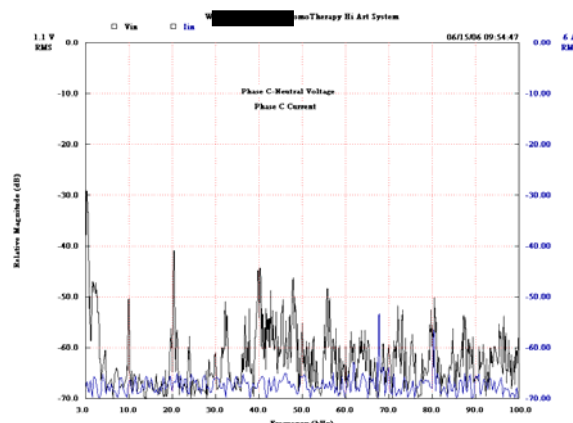
Pre Rad-X Filter Activation



Post Rad-X Filter Activation



Pre



Post