GE PETtrace RF Power Failures Related to Poor Power Quality

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Introduction

The University of Iowa Hospitals and Clinics completed installation of a GE PETtrace 800 cyclotron in November 2011. Four months prior to installation, GE service personnel arrived to do a power assessment. The result was that we met their specifications, but with reservations. We could easily provide the quantity of power required, but the specification also states that GE recommends that primary power remain at 480 VAC +/- 5%. GE service personnel attached a power quality analyzer to the cyclotron main power panel and determined that we did have some events of 7 to 8% sag, but they were infrequent, perhaps once or twice a week lasting 20 to 50 msec. Sags were confirmed to be the result of large non-linear loads elsewhere in the hospital. If these occurred during a run, they may shut down the cyclotron, specifically the RF power supply. Further investigation revealed the presence of harmonics on our power. Harmonics are the multiples of 60Hz power that are reflected back into the facility's power grid. Variable frequency drives (VFDs) on large motors were responsible for much of the harmonic distortion in our facility. Commercial air handlers, water pumps and fan motors often use VFDs for proportional control to adjust to changing facility demands. Their use provides a significant on-going cost savings, but may play havoc with power quality throughout the institution.

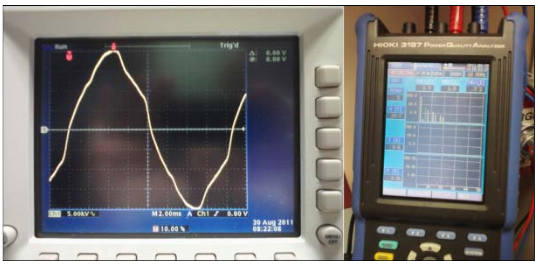

IMAGE 1. 480VAC with harmonic distortion (left) and power quality analyzer (right).

Harmonic distortion is often quantified as a total harmonic distortion (THD) percentage. Though not specifically mentioned in the site-specifications, our experience here will show that it is important not to overlook harmonic distortion. Its effects can be varied, erratic and wide-spread throughout the cyclotron system. When asked, GE service referred us to IEEE standards for electrical systems and equipment which states that THD is recommended to be below 5% for most applications, but below 3% for sensitive settings including airports and hospitals[1].

Mitigation of voltage sag and harmonic distortion is an expensive and complex topic. It is recommended that you consult with your cyclotron vendor to determine if there exists a field-tested solution. Additionally, you should consult a power systems specialist to do an audit of your building's power system.

Anyone who has ever overseen the installation of a new cyclotron is aware of the importance of addressing the numerous vendor-supplied site specifications prior to its arrival. If the site is not adequately prepared, the facility may face project cost overruns, poor cyclotron performance and unintended maintenance costs. The cyclotron vendor will provide you with a set of site specifications, but meeting these specifications can be difficult, especially when the cyclotron is placed in an existing structure. The cyclotron is an interesting collection of power supplies providing power to sensitive electronic circuitry. It is not sufficient to just provide enough power; you must also provide quality power. It is hoped that our efforts to resolve our poor power quality problems will assist others as they replace aging cyclotrons in existing institutions whose power quality has degraded over the years.

Material and Methods

Characterization of Power Quality: This was accomplished using a Hioki 3197 Power Quality Analyzer and a couple Dranetz PX-5 Power Xplorers. Each of the monitoring cycles logged data for about a week, which seemed to be about the limit for these units when logging both THD and surge/sag events down to the duration of a single 60Hz cycle. Analysis of the circuit diagrams and communication with GE engineers indicated that the main power contactors to the cyclotron RF system were disengaging to protect the system. The feedback for this shutoff is a detection signal from the front-end EHT (high-voltage generation) circuit that is set to disengage the main RF power contactors at a level to be representative of the 5% AC deviation specification.

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RF Power System Contactors: Every time the contactors of the RF power distribution system are energized/de-energized, some arching occurs at the contact surfaces. This arching pits the contactor surfaces such that over time the contactor surfaces become irregular and potentially resistive. Since the RF protection circuit triggered by the EHT circuit is downstream from the contactors, it is not so hard to envision why the system becomes more sensitive over time[2].

IMAGE 2. RF power distribution contactors (left) and their pitted contact surfaces (right).

Additionally, the harmonic distortion also exists on the AC voltage energizing the contactors. As a result, they may not actuate as smoothly (dependent of degree of harmonic distortion) and further hasten the normal rate of pitting of contactor surfaces.

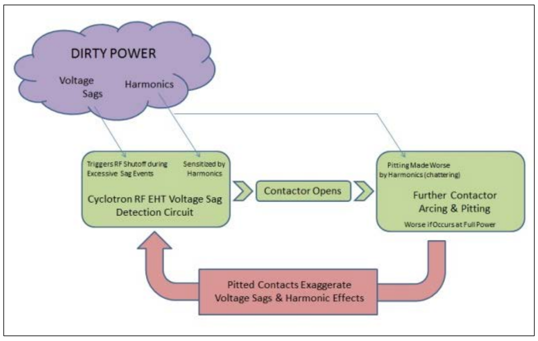

IMAGE 3. RF power shutoff circuit showing the effects of dirty power and cyclic worsening with each shutoff event.

Results and Conclusion

Within weeks of installation, we began to get RF power shutoffs. They were infrequent at first, but soon began to occur numerous times each day. At approximately 3 months post installation, it was often difficult to get through a standard 30 to 45 minute bombardment to make F-18 for our daily patient FDG doses. During that time, we discovered that replacing the RF contactors significantly reduced the frequency of shutoffs. But, without resolving the harmonic distortion and sag issues, the frequent failures would soon return. We limped along for over a year until the University was willing to invest in a solution to address our power problems.

Periodic Power Analyses: These analyses, performed over the next year, indicated that our power quality worsened in the winter and returned to functional levels in the summer. The instance of voltage sag remained approximately the same throughout the year (a few short sags per week), but the THD was down to 6% in the summer and nearly 10% in the winter. This result, combined with RF shutdown tracking and lack of correlation between observed power sags and RF shutdowns, led us to the conclusion that our very high harmonic distortion combined with small power fluctuations (< 5%) were the culprit.

Mitigation Planning: There are a number of power conditioning technologies, but imposing the need to remove both voltage sag as well as harmonic distortion, quickly narrows the field. What remains are the following options: 1) UPS line conditioner with batteries, 2) UPS line conditioner with flywheel or 3) motor-generator power isolator. Battery maintenance costs ruled out the UPS battery line conditioner. Of the remaining two, if you have the space, the motor-generator is the simplest and cheapest (favored by forward military hospital units). But for the space constrained user, like us, the UPS flywheel line conditioner became the preferred option.

Additionally, it was identified in a power audit that the THD was only 4% at the transformers connected directly to the local power utility company supply (upstream of load effect and harmonic distortion sources). This was to be expected as load effects and harmonic distortion are worse if your tie-in point to the building power grid is at the same level or downstream of their sources. Additionally, a test was performed during a hospital backup generator test, wherein the suspected primary offenders (large motors and VFDs) were diverted to backup. As a result, the THD measured at the cyclotron primary power panel dropped by 2.5%.

Working with University electricians, an outside power consultant, GE engineering and University Hospital Radiology Engineering, a two phase plan was created.

Phase 1: With a repurposed utility transformer, the cyclotron and PET cameras got their own dedicated transformer connected to the main utility power feed. We also replaced the old contactors in the RF power distribution system. Since installation, the measured THD has re-

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mained at 4.5 to 5% year round and the sag incidence and magnitude are slightly improved.

Phase 2: With a quote from GE for a flywheel UPS we should be able to fully condition the power entering our facility, removing the load effect voltage sags as well as the harmonic distortion.

One year of operation after Phase 1 implementation, it has been decided that Phase 1 was all that was required. We haven't had a single new instance of RF shutdown since.

References

1. *IEEE Standard 519-1992 Recommended Practices for Harmonic Control in Electrical Power Systems, , Table 10.2,* 1992.
2. A. B. Baggini: *Handbook of Power Quality, Section 7.6.12 Relay and Contactor Protective Systems*, pp. 234-235, 2008.

Acknowledgements

Throughout this process, GE Medical Systems service group was extremely forthcoming and provided much useful information necessary to resolving our power problems.

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