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FONAR Passes

Voltage regulators provide a clear solution for stand-up MRI

As the world's only manufacturer of stand-up MRI, Fonar is accustomed to forward thinking and problem solving. Its revolutionary equipment allows doctors to scan patients in a weight-bearing state, in a recumbent position, or both—then compare the results. Rugged and reliable electro-magnets at the heart of the system yield excellent image clarity. Providing a stable power supply to the electro-magnets is vital to ensuring this high degree of reliability and image clarity.

Several stages of regulation take place in order to control the voltage to a few parts per million. The critical first step is regulating the incoming line voltage. Incoming line voltage—which is normally supplied at ±10% is regulated to ±1%. Output from the voltage regulator is sent to a power supply where it is converted to direct current with a stability of 1 ppm.

How important is the initial stage of the process? In areas that are prone to brownouts, voltage fluctuations can have disastrous effects. "In a best-case scenario, it would require the technologist to repeat a scan," comments Fonar's Director of Electrical Systems Engineering Mark Gelbein, "In the worst case it would turn the scanner off. A technician would then have to restart the system after the voltage dip had passed." Although the time required for the magnet to re-stabilize is brief, it could seem like an eternity to an anxious patient.

Because of the high power (225 kilovolt-amperes [kVA]) required to power the electro-magnets, the Fonar design team originally considered tap switchers, ferroresonant type voltage regulators, direct sine wave synthesis, and Staco variable transformer controlled voltage regulator.

Three Key Considerations

Three parameters were vital to Fonar's final decision. From a performance perspective, the input line voltage, which is typically ±10%, has to be regulated to ±1%. Each of the considered technologies is capable of achieving this level.

The unit has to perform reliably on a daily basis with Fonar's low-impedance power source requirements. Linear rather than stepped regulation was required, since any transit voltage jumps would disturb the power supply, translating to output disturbance—which is unacceptable.

FONAR Passes Its MRI

Ferroresonant constant voltage transformers use a capacitor in series with the transformer coil and tend to be high-impedance devices. Additionally, their sensitivity to load changes and inability to handle high in-rush load well compounded the reliability problem. Further, because they can interact with switch- mode power supplies to produce transients and electrical (output) noise, their resonant circuits make them particularly sensitive to frequency changes. The compound effect of these multiple reliability issues ruled out ferroresonant technology.

Other technologies such as tap-switchers use solid-state switching circuits for changing taps on transformer for regulation. Although these regulators are fast, this fast response time can often create instability when powering equipment with switch-mode power supplies. Their output waveform tends to produce harmonics and radio frequency. The combination of these undesirable attributes made tap switches a less than optimal choice.

The voltage regulator suggested by Staco Energy Products utilizes a variable transformer/buck-boost transformer design. The buck-boost transformer reduces the work the variable transformer must perform and multiplies the power rating of the transformer. The buck-boost reduces the current per coil requirement of the variable transformer, which results in increased mean time between failures (MTBF)—a key measure of reliability.

Additional reliability-oriented advantages include the ability to withstand substantial current overloads, no additional harmonics or wave form distortions, a low impedance (less than 1%), high overload capacities (1000% for 30 cycles), attenuation of electrical noise, and imperviousness to frequency changes.

The final parameter within the decision making process was cost. While each of the technologies can regulate voltage to the ±1% design specification, at the 225-kVA operating level that Fonar requires, it was cost-prohibitive for all but the voltage regulator to do so.

Meeting Customer Need

Many Fonar installations are used in 480-volt (V) service, so the standard model 225-kVA voltage regulator suited their needs and met the budget requirements. For 208-V installations however, the task of voltage regulation was disproportionately expensive.

Without accounting for power factor, kilovolt-amperes or kilowatts both are defined as volts times amps. So at a fixed kilovolt-amperes level (in Fonar's case 225), as volts decrease, amps increase. At 208 V, the amps essentially double so the magnetic components are twice as large and the unit is bigger, heavier, and more expensive.

"We had a 208-V unit that was 50% more expensive than the 480-V model" comments Gelbein. "So we asked Staco what they could do to meet our cost parameters without reducing the performance."

Staco Energy Products R & D custom engineered a solution at a price point required by the customer. By including an autotransformer to step up the line voltage from 208 to 480 volts, Staco Energy engineers were able to use standard 480-V components. This significantly reduced the cost of the 208-V version, while providing the proven performance of the larger model.

Site Specific

Although the doctors operating the stand-alone imaging centers are the ultimate end-users of Fonar products, Staco Energy products are generally made by contractors during the installation process. To accommodate varied installation parameters, Staco voltage regulators are available in NEMA 1 indoor or NEMA 3R outdoor enclosures. Regardless of the enclosure chosen, the regulators are 100% front-serviceable and fit through a 25-in. opening. No cooling fans are required. Extremely short lead-times are achieved through cellular production and streamlined manufacturing.

In addition to voltage regulators, Fonar uses a Staco Energy single-phase UniStar II UPS system to ensure uninterrupted power to the patient table—allowing technicians to remove a patient from the gap of the magnet in the event of a power failure. This double-conversion, regenerate power, true on-line UPS provides clean, regulated, harmonic free, sinusoidal voltage and frequency. In addition to maintaining compliance with IEC601-1, this design makes good sense as it allows technicians to remove the patient quickly (far quicker and more professionally than a manual crank might).

As is often the case with complex technologies, the success of Fonar's stand-up MRI hinges on several components working together. Tight regulation of the incoming line voltage provides a stable input to the power supply which in turn produces a very tightly controlled direct current output that powers the electro-magnets. *e&pm*