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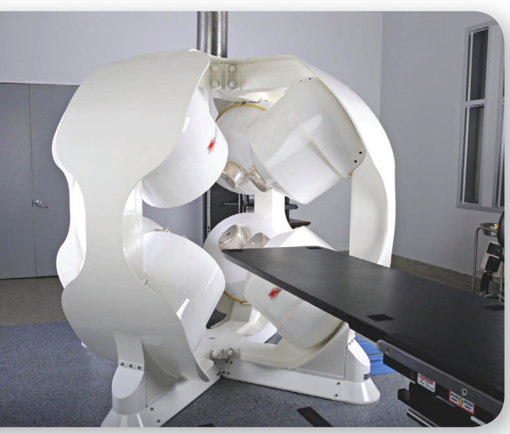
Redundant PLC controls heart-mapping machine

Getting the Magnetecs catheter guidance system into human clinical trials fast depended on choosing capable partners, and selecting a control platform with easily implemented hot back up capability.

Manually navigating the twists and turns of an artery, and performing a therapeutic procedure within a human heart, demand high degrees of surgical training, practice and manual dexterity. A wrong move could tear a blood vessel or puncture a heart wall. Aerospace and defense technology pioneer Josh Shachar knew automation could deliver a better way to move an electrophysiology (EP) catheter than by hand. He envisioned a system that would use electromagnetic fields, instead of manual prodding, to help a physician perform the procedure.



The computer-based CGCI system creates three-dimensional graphical displays of cardiac structures and arrhythmias, providing the physician with precise targets for cardiac ablation. Electrical controls engineer Mason Mattenson put the control system together with help from industrial automation distributor RK Controls. Source: Siemens

Shachar, founder and president of Inglewood, CA-based Magnetecs and maker of the Magnetecs Catheter Guidance Control and Imaging System (CGCI), says, "At the core of any engineering task is the fundamental and unassailable belief that a solution is possible." What comes next is a combination of vision, teamwork and technology that can implement the solution and, in this case, get a new medical machine into human clinical trials fast. A control platform with easily implemented hot back up capability was one of the keys.

"The speed of getting CGCI to human clinical trials would not have been possible if Magnetecs chose a different platform," says RK Controls general manager Robert Karkafi. "I have seen companies using other platforms where they have spent months and months writing code to make sure the hot back up is operating correctly." Magnetecs' choice, however, came preprogrammed as a standalone unit.

Physicians rely on cardiac ablation to treat arrhythmia — an abnormal heartbeat — in a procedure using an EP catheter pushed by hand through a blood vessel into a heart chamber. When the normally operating electrical system of the heart is blocked or travels erratically, it creates a "short circuit" that disturbs normal heart rhythms. Often the most effective treatment is to destroy the tissue at the location of the short circuit using the EP catheter for cardiac ablation. Beginning in 1997, Shachar, later joined by Magnetecs' chief scientist Laszlo Farkas and vice president of engineering Leslie Farkas, produced several promising, small-scale prototypes. Today, the CGCI system they developed is entering the human testing stage.

Focused magnetic waves

The system employs magnetic waveguide forming technology that focuses magnetic waves like light through a lens to generate a magnetic lobe (about the size of a basketball) around the tip of the catheter. The magnetic lobe is formed by eight electromagnets that surround the patient's torso. A real-time, computerized controller calculates the current values for each electromagnet; the signal from the controller is amplified by eight, high-efficiency amplifiers.

By altering the polarity and current of each coil with a joystick, a surgeon can reshape the magnetic lobe in milliseconds and employ five degrees of freedom in 3D space to move the flexible, magnetic tip in synchronization with a beating heart. The system allows extensive maneuverability without generating enough force on the tip to damage or puncture a blood vessel or heart tissue. CGCI also could enable other advancements, such as controlling un-tethered cameras and probes within the body.

Magnetecs chose a programmable logic control (PLC) system from Siemens to provide automated and redundant safety monitoring and smooth startup and shutdown of the CGCI system. The Simatic S7-400H redundant controller system, programmed with Step 7 software, ensures that CGCI performs safely and with high availability. "We originally used our own software to control all aspects of turning the system on and off," said Leslie Farkas. "Additionally, our systems were initially responsible for validation of the hardware and its reliability, but there was no redundancy."

In January 2009, Magnetecs hired Mason Mattenson, an electrical controls engineer, to design, install, and program the redundant control system. Mattenson's previous automation experience included an array of projects, from high speed amusement rides to national defense systems using Rockwell Automation Allen-Bradley control platforms.

This was Mattenson's first experience with a Siemens platform, and he was given just four months to complete the project. "My challenge was making sure that the S7 400H fit our needs. I checked every module, I/O, and device that was installed in this system to ensure successful interface with the Siemens platform," he said. The project's complexity was compounded by the constant addition of new modules or pieces of equipment to the system design.

Mattenson got help from Siemens' high-tech industrial automation distributor RK Controls, who provide valuable support. "The I/O list changed frequently in development, and each delivery was well planned and organized. All of the documentation came with the proper components. Great service kept logistical issues at a minimum, so I could focus on the technical aspects of the project." Mattenson also attended the Siemens "AB to Step-7" course, which focuses on transitioning from Allen-Bradley to Siemens technology, and helped speed the learning process.

Within a very short time after joining Magnetecs, Mattenson had the entire system configured in his office. He was quickly demonstrating communication with all of the input and output modules and the redundancy of the system. One day before the deadline, the CGCI system was operational. "In the end, Mason and I wired up the system, turned it on, and there was not one wire out of place," Farkas said.

How redundancy works

The S7 400H controllers have preprogrammed failover routines developed by Siemens as a standalone redundant CPU system. That meant Mattenson did not have to worry about any of the background code that moves information from the active controller to the standby unit. Communicating via Profibus over fiber optics, the active S7 400H controller monitors and controls the critical system parameters and functions of the CGCI, including system startup and shutdown, system fault monitoring and emergency stop. The controller also monitors amplifier command current vs. actual coil current as well as coil cooling and temperatures, flow, and alarms.

If an amplifier module faults, the controller automatically determines the cause of the problem. If the fault did not affect any part of the clinical procedure, the PLC does not send an alarm to the physician's central monitor, but instead internally logs the event on a human machine interface (HMI) programmed with Siemens WinCC SCADA software located in the equipment room. If the controller can't reset the fault, it starts a warning procedure.

The controller and the patient

However, if the fault causes a change to the clinical procedure — such as when a coil or a combination of coils develops a heating problem — the controller corrects it or goes into a lower power state and alerts the EP physician. The physician can then decide whether to proceed. If the temperature continues to climb and the coil is overheating, the controller will tell the physician it is using lower power and, again, the physician decides on the next steps.

"The controller is out of the decision-making loop for patient safety," Farkas says. "It keeps the system from hurting the patient and itself. It is a watchdog, and it reduces the chances for error."

The data logging and remote communications capabilities of the WinCC HMI will also help hospitals lower maintenance costs, Farkas said, by reducing the need for representatives and technicians to troubleshoot the system. If an event occurs, the WinCC HMI records the occurrence and provides additional data on the cause of the problem: "We have the forensic capability to make very quick decisions. We can log on to any installation, anywhere in the world, and see the trend. In fact, our computers will be programmed to monitor every unit. We can contact a hospital even before its staff knows there is a problem."

The CGCI system is expected to change the way EP procedures are performed on a global scale. The engineering teams from Magnetecs, Siemens and RK Controls have taken the concept of the CGCI's waveguide forming technology from "it cannot be done" to human testing quickly and efficiently. Thanks to these partnerships, safer and easier procedures will soon be available.

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Magnetecs chose a Simatic S7-400H PLC from Siemens to provide automated and redundant safety monitoring, and smooth startup and shutdown of the CGCI system. Source: Siemens

CGCI is operated from the control room or the operating room. Remote Web-based interfaces are not yet available or approved by regulatory authorities, but are likely to become a reality, enabling robotic surgery to be performed from anywhere in the world. Source: Siemens