Advancing Nuclear Energy with Tektronix Oscilloscopes At Cornell University

Solution Summary	
Challenge	Measure current, voltage, and emitted signals during the high energy density plasma production process
Solution	Tektronix TDS5000 Series digital phosphor oscilloscopes and Tektronix TDS6000 Series digital storage oscilloscope
Benefits	High sample rate, extended record length, and surprising durability

The Center for the Study of Pulsed-Power-Driven High Energy Density Plasmas at Cornell University was established to study exploding-wire-generated plasmas and their applications. This work is being carried out by the university's Laboratory of Plasma Studies in collaboration with research institutions in Nevada, London, Israel and Moscow.

Although the study of exploding wires may sound simplistic, the research and experiments being conducted by Cornell are highly sophisticated. There are various applications for the high energy density plasmas that are produced through the experiments, yet none are more significant than ultra-modern nuclear energy.

Today's nuclear energy is produced through nuclear fission, a nuclear reaction in which an atomic nucleus is split into fragments. However, the process creates a large amount of toxic radioactive byproducts.

In contrast, the Laboratory of Plasma Studies at Cornell is researching inertial fusion, in which nuclei are combined to create a nuclear reaction. The process generates more energy per gram than traditional fission and produces only benign Helium as a byproduct.

In order to understand and harness the power of inertial fusion, Cornell faculty and students carry out experiments that address the fundamental physics of exploding wires and multi-wire arrays in different arrangements. The basic configuration is a current-carrying plasma column in which the current is sufficiently high so that the resulting plasma implodes upon itself due to the magnetic forces. This configuration is commonly called a z-pinch, which refers to the z-axis of a cylindrical coordinate system.

The university is utilizing a pulsed power generator to produce the immense current that flows through the wires, creating and then imploding plasma. The generator reaches 500,000 volts, achieves 1 million amperes of current, and produces a half terawatt of power. Since the generator is exceedingly powerful, it only produces extremely short bursts to avoid too much energy storage.

Because the energy bursts are lightning fast, Cornell needed highly advanced instruments to acquire and measure the physical properties of the generator's output and the plasma it produces. The university required test and measurement tools that could monitor the voltage and current levels created by the generator as well as the signals discharged by the plasma throughout the z-pinch implosion process.

"Not many instruments can withstand the "noise" voltage we produce, let alone measure pulses that rise at one-tenth of a nanosecond," said Dr. David Hammer, J. Carlton Ward Professor of Nuclear Energy, Cornell University. "Remarkably, Tektronix instruments have been able to handle our needs without difficulty. Our pulsed power generator puts on quite a show, and Tektronix oscilloscopes give us an impeccable view."

Cornell utilizes three Tektronix TDS5054B oscilloscopes and one Tektronix TDS6404 oscilloscope during the plasma production process. Together, the instruments monitor and measure 16 channels – four each for voltage and current, and eight for plasma output – as faculty and students conduct high-energy density experiments.

The TDS5000B Series digital phosphor oscilloscopes (DPO) deliver up to 1 GHz bandwidth, 5 GS/s real-time sample rate, 8 MB record length and 100,000 wfms/s maximum waveform capture rate. The instruments provide unmatched insight into signal behavior by displaying, storing, and analyzing complex signals in real-time using three dimensions of signal information: amplitude, time, and distribution of amplitude over time. Powered by Tektronix' exclusive DPX™ acquisition technology, the oscilloscopes deliver fast waveform capture rates to quickly reveal the nature of faults so sophisticated trigger modes can be applied to isolate them.

"Not many instruments can withstand the voltage we produce, let alone measure pulses that rise at one tenth of a nanosecond. Remarkably, Tektronix instruments have been able to handle our needs without difficulty."

- Dr. David Hammer, J. Carlton Ward Professor of Nuclear Energy, Cornell University

The TDS5000B Series' powerful and flexible measurements, math, and math-on-math capabilities make it an ideal solution for Cornell's experiments. The instruments offer functionality to capture important measurements, such as voltage, current, instantaneous power, and energy.

"The TDS5000B Series oscilloscopes are our workhorses, constantly measuring the voltage and current produced by the pulsed power generator," noted Dr. Hammer. "But the TDS6404 is the real star of the show. It is one of a few instruments in the world that is able to acquire the ultra-short pulses emitted from high-energy density plasmas. And those are the signals that provide the greatest insight into plasma behavior."

With up to 6 GHz bandwidth and 20 GS/s sample rate on 2 channels or 10 GS/s sample rate on 4 channels simultaneously, the TDS6000 Series digital storage oscilloscopes provides unmatched signal integrity measurements. And through exceptional trigger capabilities, outstanding acquisition performance, and application software, the instruments offer Cornell high performance jitter analysis down to 0.7 ps_{RMS}.

According to Dr. Hammer, the record length of TDS5000B and TDS6000 Series oscilloscopes provides a key benefit in monitoring and measuring the plasma production process.

"The current and voltage produced by the pulsed power generator can be many microseconds long, and we need measurement tools that contain sufficient record lengths without sacrificing sample rate," he said. "The combination of high bandwidth and extended record length offered by Tektronix oscilloscopes is perfect for our experiments."

Durable Tektronix Instruments Survive Where Others Have Perished

In generating a half terawatt of power, the pulsed power generator also produces intense electromagnetic "noise" fields in its laboratory. Cornell previously attempted to utilize oscilloscopes from another leading manufacturer during the plasma production process, with less than impressive results.

"We went through three high-performance, non-Tektronix oscilloscopes. Their tolerance for noise was unacceptable – they simply couldn't endure the environment in which we operate. We ended up with three burned out input amplifiers," said Dr. Hammer. "The TDS5000B and TDS6000 Series oscilloscopes have proven to be rock solid and highly durable. We haven't had a single problem."

Dr. Hammer is confident that the university's new oscilloscopes will serve the Laboratory of Plasma Studies well into the future. "I've been doing this for a long time and have always had an affinity for Tektronix instruments," he reflected. "In fact, we have some vintage Tektronix oscilloscopes from the 1950s in one of our other labs, and they still work amazingly well."