PHOENIX NUCLEAR LABS

PROVIDING NUCLEAR TECHNOLOGY FOR THE BETTERMENT OF HUMANITY

A New High Voltage Power Supply for Fusion Research and Applications

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Dr. Gregory Piefer
Email: greg.piefer@phoenixnuclearlabs.com
Phone: 877-253-5799

Talk Overview

- Introduction to Phoenix Nuclear Labs
- Motivation for developing a power supply
- Product features
- Product development and testing

About Phoenix Nuclear Labs

- Founded in August, 2005 with the mission to commercialize near term applications of nuclear technologies
- Located in Middleton, WI; 5000 ft^2 lab, including office space, machine shop, test and assembly area, and bunker
- Lead by Dr. Gregory Piefer, advised by Dr. Paul DeLuca (UW Provost), Dr. Thomas “Rock” Mackie (TomoTherapy), Dr. Harrison Schmitt (Apollo 17), and Scott Klug (U.S. House of Representatives)
- Near term focus is on medical and defense applications of fusion
- Also interested in selling technologies developed to facilitate fusion

Motivation for Developing a Power Supply

- The present markets for fusion research and applications demand an efficient, high power, high voltage power supply
  - Neutron systems require up to 300 kV at tens of kW
  - Proton systems require up to 500 kV, also at high power
- Protection of delicate equipment essential
- Also important: safety, durability, resistance to EMI, low ripple, computer control
- *Until now, nothing on the market could meet these needs*

PNL Has Developed a System to Meet These Needs

- New power system developed, tested and is now being sold
- Present model supports up to 300 kV unipolar output, next generation to support up to 500 kV
- Primary features
  - High voltage and high power—units available up to 300 kV, 90 kW
  - Unprecedented time to power system shutdown: < 50 μs
  - Low stored energy: < 150 J at full voltage
  - Low ripple: < 0.6% at maximum rated current
  - High “wall plug” efficiency: > 90 %
  - PLC control
  - Fiber optic control signals protect user and are immune to EMI
  - High frequency: 400 Hz minimizes size of magnetic components

Power Supply Development Posed Many Challenges

- 300 kV high voltage section
  - Electric field control very challenging
  - Tank cleanliness and oil purity of critical importance
  - Individual components require thorough testing
  - High voltage, current necessitate consideration of parasitics
  - Mistakes can be very expensive
- Control system / driver circuitry also challenging
  - Fast shutdown requires IGBT “switching” system
  - Switching must be fast for good efficiency
  - But fast switching causes displacement currents that can destroy high voltage components
  - Series resonant sine-wave filter developed to solve this

Development Occurred in Several Phases

- Development of control and power feed systems
  - Electrical
  - Mechanical
- Software
- High voltage component design and testing
- High voltage system mechanical design
- Oil filling and drying procedures
- Complete system testing

Control and Power Feed Systems

- IGBT system had several bugs resulting in destruction of the semiconductors
  - Improper phase balance at low output lead to a small DC voltage on an AC system
  - Testing done at PNL lead to an entirely new firmware release for all new Rockwell drives
- Proprietary control boards for signal processing and high speed shut down developed
- All components mounted into a high quality sealed enclosure for durability and long life
- User controls very rugged
- Internal layout designed to minimize electrical interference between power system and signals

High Voltage Component Testing

- Independent testing required on many components
  - Many components not rated on important parameters (maximum voltage, surge energy, etc.)
  - Unexpected component failures can damage other components
- Special test equipment designed for testing
  - Surge energy: test repeatedly to 10x stored energy
  - High voltage transient: test repeatedly to 50% overvoltage
  - Teraohm meter for checking diode bridge balance
  - Chemical compatibility test

High Voltage Section

- Most challenging component was high voltage transformer
  - High field stress, coils in close proximity necessitate anti-corona, combination of solid and liquid dielectric materials
  - AC behavior makes displacement currents damaging to solid insulation
  - Design needed to be physically robust as well
- Other high voltage components mounted to dielectric wall
  - Mechanically robust mountings designed
  - Electrical connections utilize large smooth conductors
- All high voltage components mounted to component frame
- Frame drops into reinforced steel tank capable of withstanding vacuum


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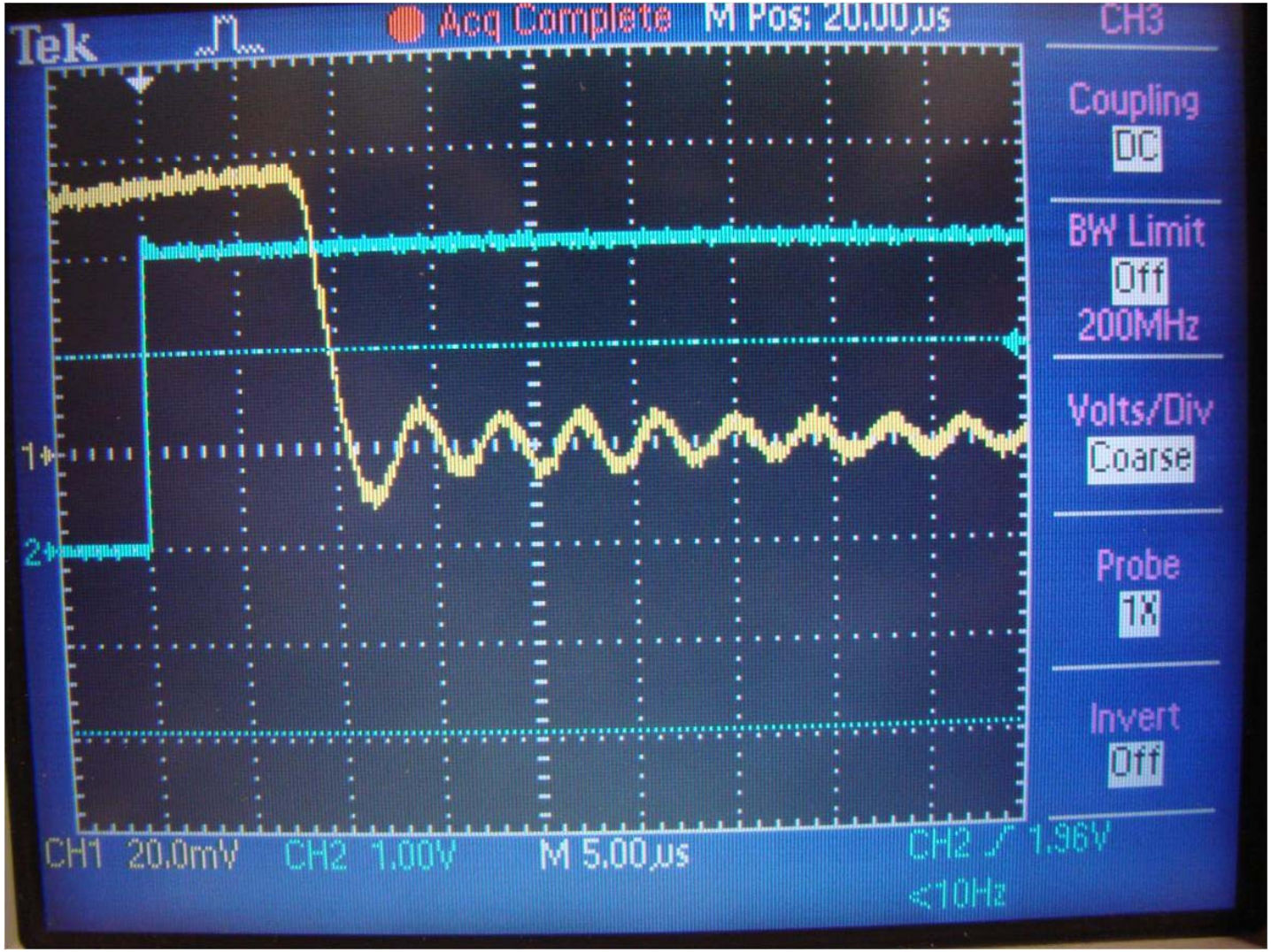
Oil Filling and Drying Procedures

- Multiple dielectric fluids were evaluated on five characteristics
  - Dielectric strength
  - Dielectric constant
  - Density versus temperature
  - Viscosity
  - Flammability
- After selection of type, oil must be cleaned and dried to guarantee maximum performance
  - Oil heated to 66 C
  - Multiple passes through 0.1 μm filter
  - Pulled into high voltage tank by vacuum, flow controlled so pressure never exceeds 1 kPa

System Test Procedures

- Overvoltage endurance test: 10% above rated voltage for 12 hours continuous
- Full load test: 24 hour test at full load
- High speed system shutdown test
- Short circuit test at full voltage, full load
- Installation at customer location with on-site testing

High Speed Shutdown



PNL is Now Selling Power Supplies of up to 300 kV and 300 mA

- Request for more information can be found at www.phoenixnuclearlabs.com/products.php
- Please see our poster, presented by Mr. Christopher Seyfert in the poster section for more information
- Also, please see the UW's 300 kV, 60 kW unit on your tour of their laboratory

Questions?

Dr. Gregory Piefer-President
greg.piefer@phoenixnuclearlabs.com
(877) 253 5799
www.phoenixnuclearlabs.com