Update on Optically Interconnected Inverter System

The DOE Workshop on Systems Driven Approach To Inverter R&D

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Overview

- USDoE Inverter Program Background
- Program Status
- Anticipated Markets
- Future

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Background: Project Goals

- **Primary: Develop and test an advanced pre-production three phase, 5 megawatt inverter system based upon HV-IGBTs switches with complete optical isolation (control and sensing) between the high power subassemblies and the low power control and signal processing hardware.**
- Secondary
  - Successfully Implement Robust Heat Pipe Thermal Solution
  - Design the System for Manufacturability "…from the Start…"
  - Build the Complete System for $150/KVA @ > 99% Efficiency
  - Develop Optical Current/Voltage/Temperature Transducers for Introduction into Other Electrical Markets

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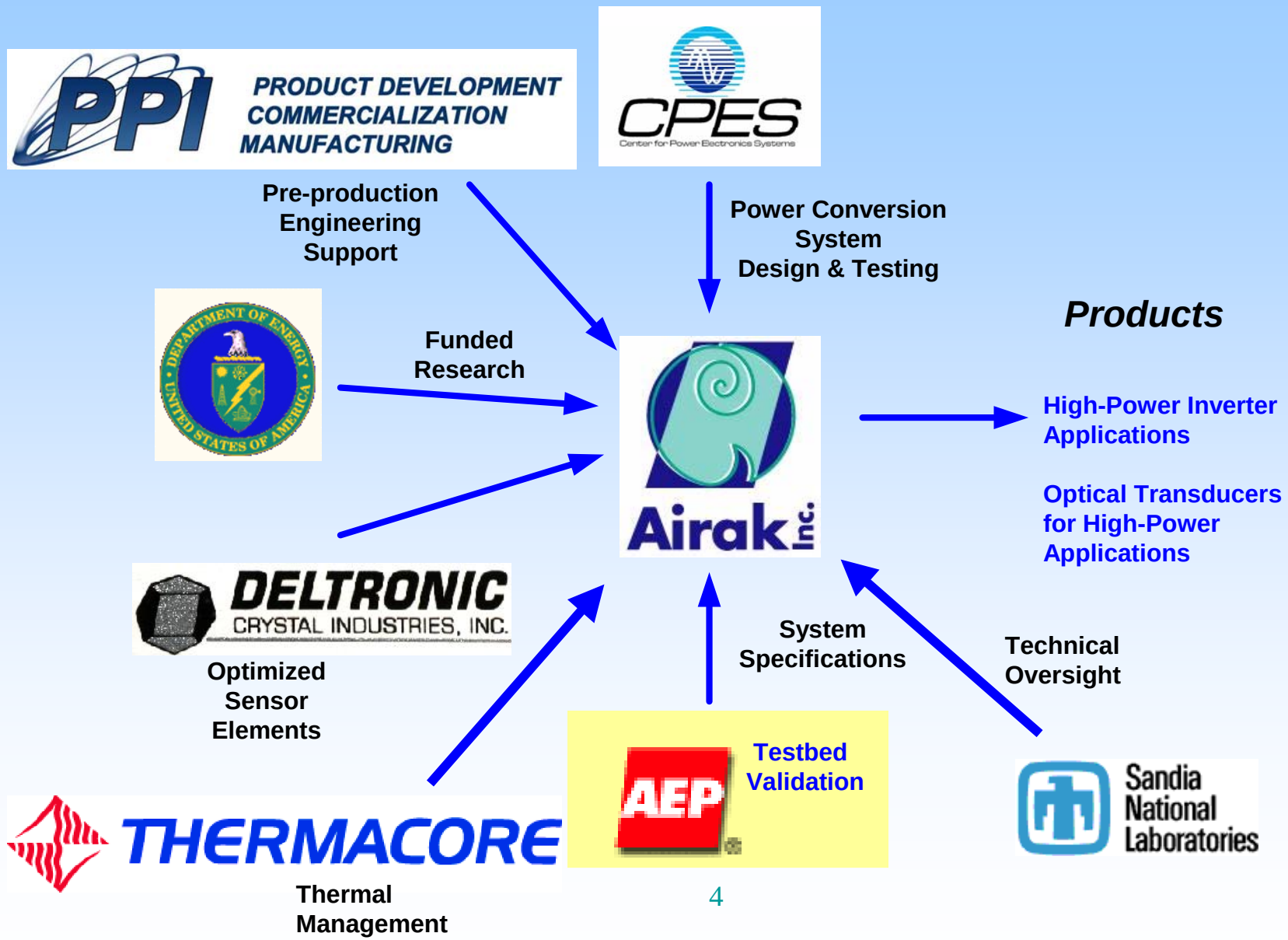
Background: Team Members



Background: Motivation

- There exist few cost-effective, efficient power conversion topologies for high-power markets.
- High-power conversion systems are largely based upon smaller conversion systems with applied scaling rules, e.g., a 5-MW system ~ size of 10, 500 KW systems.
- There are no optically-isolated/interconnected high-power systems in the market today.

- Solution: Optical Sensor Technologies + High-Voltage IGBT Power Systems + Advanced Heat-Pipe Cooling Solutions

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Background: System Advantages

- HV-IGBT Topology Allows:
  - Elimination of Current Snubbers and Voltage Clamps
  - Simplified Gate Drive Circuitry and Isolation
  - Higher Frequency Switching (~ 5 kHz)
- Optical Transducers and Interfaces Allow:
  - Intrinsic Galvanic / Electrical Isolation
  - EMI Immunity => Increased Reliability
  - Increased Equipment and Personnel Safety

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Background: System Advantages (Con't)

- Integrated Heat-Pipe Cooling System Allows:
  - Considerable Life-Cycle Cost Reduction over Conventional Pumping Systems
  - Lower (Minimal) Maintenance Requirements
  - Higher Reliability
  - Smaller Footprint / Compact Design
  - Degraded Mode of Operation Possible
  - Up to 20 KW Heat Removal per Phase Leg

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Mitsubishi HV-IGBT Packages

- Common 190 x 140 mm Footprint
  - CM1800HB: 1.7 KV, 1800A
  - CM1200HB: 2.5 KV, 1200A
  - **CM1200HB: 3.3 KV, 1200A**
  - CM900HB: 4.5 KV, 900A
- Scaleable Phase Leg Designs Possible
- Efficient Interface to Buss Bar

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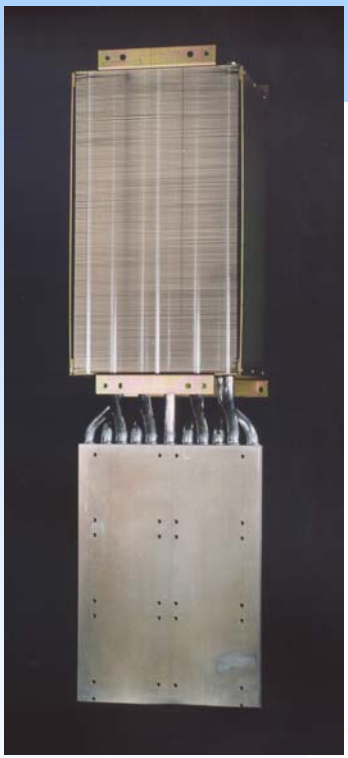
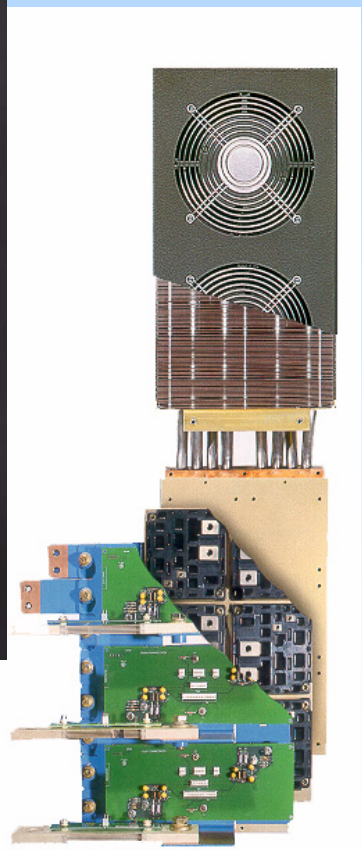
Therma-Charge™ Multi-Kilowatt Heat Pipe Heat Sink





Power Rating: 10,000 watts (Modified Standard 835 Design)

Nom. Air Flow: 600 CFM per 2 Fans

Working Fluid: Water

Operating Range: 40° C – 180° C

New Design Tested to Δ43° C at 8250W True Power Dissipation

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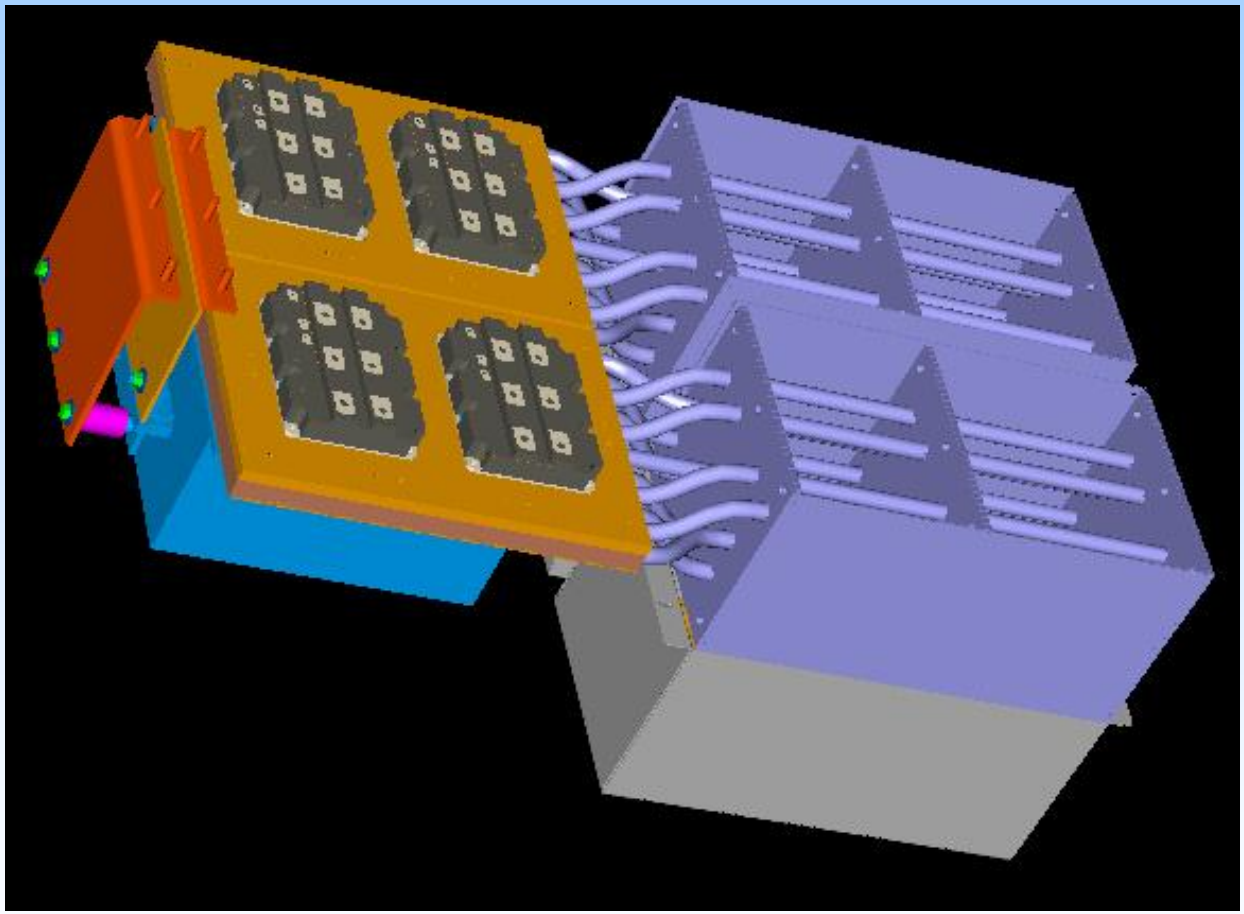
1700 KVA Phase Leg Topology



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PPI PRODUCT DEVELOPMENT COMMERCIALIZATION MANUFACTURING

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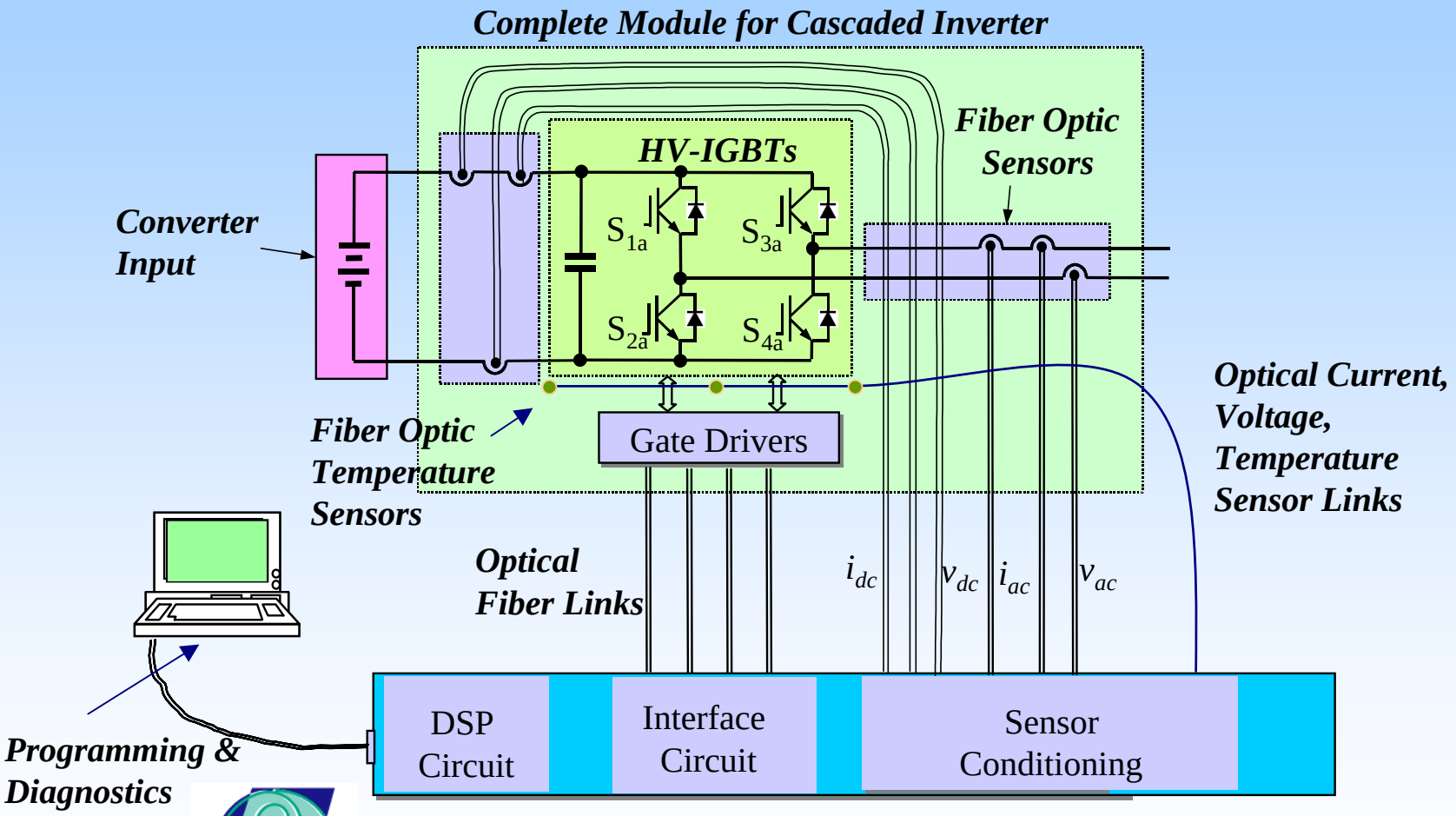
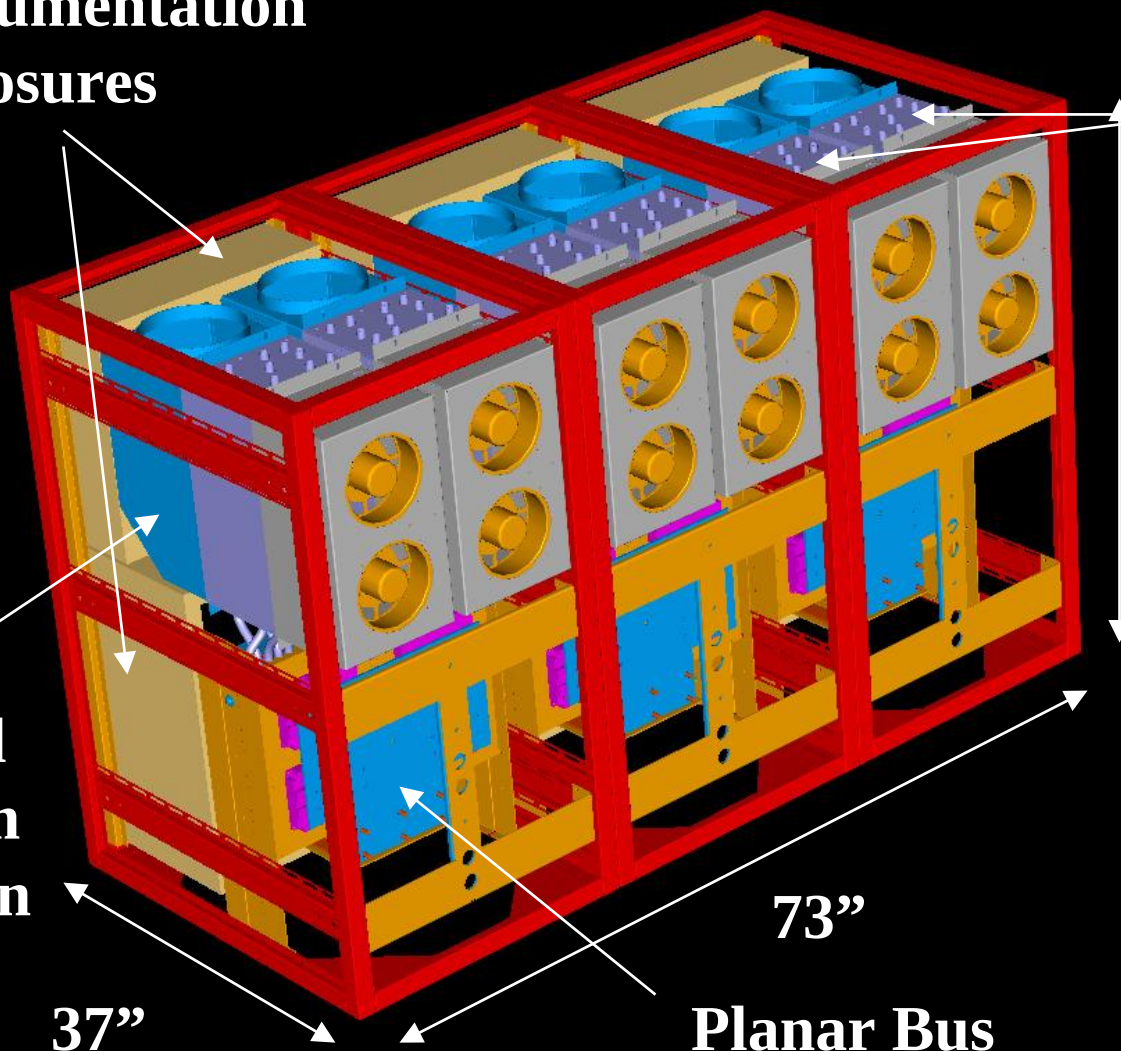
Single Phase Building Block

Sensor & Control Configuration



5-MW 3-Phase Multi-Level Inverter



Rationale for CAD Effort

- Ensure Everything "Fits" / Get it Right the First Time
- Self Documenting for Manufacturing / More Cost Efficient
- IDEAS™ Models Directly Import Into Maxwell 3D for Field FE Solver Calculations
  - Parametric Solver Shows Optimum Placement of High-Power Cables, Interconnecting Buss Bars, etc.
  - ES and EM Shielding Requirements for 5-MW Operation can be Inferred from 300 KW Model Convergence ➔ Greater Chance of Success @ 5 MW

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PPI PRODUCT DEVELOPMENT COMMERCIALIZATION MANUFACTURING

Program Status as of 4/23/03

- Currently In Month 11 of 24 Month Program (Full Contract Awarded September 26th, 2002); Program is On Schedule
- All Major Subsystems have been Implemented in CAD-Space
- All Major Hardware has been Procured and Receipt is Anticipated by End of April
- Closed-Loop Control System Development Underway

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Single Phase-Leg Size Reference & Major Components

Cooling Fins

Cooling Fans

Heatpipes

Copper Thick-Block

I/O Cable Support

850 uF Capacitor

Program Status (Con't)

- Optical Current Sensors are Undergoing Extensive Temperature Testing to Ensure Long-Term Performance
- Optical Temperature Sensors are Ready for Integration & Testing
- The Packaging for the Optical Voltage Sensors is being Developed for Integration into the Planar Buss Bar

Anticipated Markets

- Emergency Power Markets
  - Short Term Ride Through Appl.
  - Longer Term UPS Applications
- Distributed Energy Markets
- Advanced Power Conversion Technologies
  - Fuel Cell Manufacturers
  - Flywheel Manufacturers
  - Wind & Hydro Turbine Mfrs.
  - Solar Manufacturers
- Military Markets
  - Fuel Cell Applications
    - ✓ Submarines
    - ✓ Afloat Forces
    - ✓ Forward Deployed Forces
  - "All Electric" Ship
    - ✓ Zonal Power Distribution
    - ✓ Prime Mover Power Conversion

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Upcoming Major Milestones

- 1700 KVA Single Phase Assembly/Testing Underway (Open Loop, Conclude June ‘03)
- Low-Power Single Phase Leg Close-Loop Testing (Start June ’03)
- 3-Phase Low-Level (<300 kW) Testing (Start Aug ’03)
- 3-Phase Inverter Delivery to AEP (1st Qtr 2004) or….?

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