Optically Isolated HV-IGBT Based 5-MW Cascade Inverter Building Block for High Power Applications

Paul Grems Duncan
Airak, Inc.

U.S. DOE Small Business Innovative Research (SBIR), Phase II Grant
DOE 2002 Project
Project Goals

Develop and test an advanced prototype 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.
Team Members

Pre-production Engineering Support

Funded Research

Power Conversion System Design & Testing

Products

High-Power Inverter Applications

Optical Transducers for High-Power Applications

System Specifications

Technical Oversight

Testbed Validation

Optimized Sensor Elements
Motivation

- There exist no 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.

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

- HV-IGBT Topology Allows:
  - Elimination of Current Snubbers and Voltage Clamps
  - Simplified Gate Drive Circuitry and Isolation
  - Access to Control Schemes that Permit Increased Efficiency and Reliability

- Optical Transducers and Interfaces Allow:
  - Intrinsic Isolation
  - EMI Immunity => Increased Reliability
  - Increased Equipment and Personnel Safety
System Advantages (Cont’d)

- Integrated Heat-Pipe Cooling System Allows:
  - Life-Cycle Cost Reduction over Conventional Pumping Systems
  - Lower Maintenance Requirements
  - Higher Reliability
Dual-Use Applications

- 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
Single Phase Building Block
Sensor & Control Configuration

Complete Module for Cascaded Inverter

Converter Input

Fiber Optic Temperature Sensors

Gate Drivers

Optical Fiber Links

Optical Current, Voltage, Temperature Sensor Links

DSP Circuit

Interface Circuit

Sensor Conditioning

Airak
Therma-Charge™ Multi-Kilowatt Heat Pipe Heat Sink

Power Rating: 10,000 watts
Nom. Air Flow: 600 CFM
Working Fluid: Water
Operating Range: 40° C – 180° C
3-Phase System Configuration

Primary Test Configuration

Optional?
Cascade Inverter Configuration

Transformerless Direct Connection
5-MW 3-Phase Inverter
Concept Packaging

AC/DC Interconnections
Inverter A
Inverter B
Bus Caps (3)
Inverter C

ThermaCharge 10kW Cooling Assys + Fan Packs (6)

Dimensions:
- Inverter A: 88”
- Inverter B: 88”
- Inverter C: 48”
- Total: 48”
Successfully Demonstrated 1400 kVA Single Phase Leg in March 2002 (details available @ www.airak.com)

Currently In Month 5 of 24 Month Program

Virginia Tech Subcontract to Deliver 300 kW Test Rectifier Started in Aug ’02

All Major Subsystems Have been Identified and Quoted

1400 kVA Single Phase System has been Transferred to Airak for Closed-Loop Control System Development & Testing
Program Status (Cont’d)

- The Integrated System Controller is Being Developed
- 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 Busbar.
Pending Major Milestones

- ThermaCharge Integration & Testing into Phase I 1400 kVA Phase Leg (Feb ‘03)
- Phase II Single Phase Leg Close-Loop Testing (Jul ’03)
- 3-Phase Low-Level (<300 kW) Testing (Jan ’04)
- 3-Phase Inverter Delivery to AEP (NLT Apr ’04)
Airak, Inc. wishes to thank the following individuals and organizations for their support on this program:

- Dr. Imre Gyuk, U.S. Dept. of Energy
- Mr. John Boyes, Sandia National Laboratories
- Mr. Stan Atcitty, Sandia National Laboratories
- Mr. David Nichols, American Electric Power
- Dr. Ali Nourai, American Electric Power
- Dr. Osman Demirci, American Electric Power