Power Electronics:
Workshop on System Driven Approach for Inverter R&D
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Outline

• Converter Overview
• Technology Features
• Major Markets
• Converter Cost
• Ward Bower (Converter Issues, Challenges, & Key Logistics Issues)
Power Electronics Connect a Power Source To a Power Load

- Convert AC to DC, DC to AC, AC to AC, and DC to DC
- Requires
  - Control Systems
  - Thermal Management
  - Protection
  - Filters
Typical System Requirements for Power Converters

- The power the converter can handle: rated power
- The size of the system: small footprint
- The speed of the system response: fast response
- Power quality it can supply: low harmonic
- The reliability of the system: long term use
- The cost of the system: low cost

Reliability and Cost are Key!
Technology Feature
1. Power Electronic Devices
2. Switching Technology
3. Control Technology
4. Passive Components
5. Packaging Technology
6. Thermal Management
7. Manufacturing Technology
Advancement of Power Devices

Source: Mitsubishi Electronics America, Inc.
Summary of Silicon Power Device Capabilities

Trends:
- Increase Voltage/Current Ratings
- Increase Switching Frequency
- Lower Switching Losses
- Improve Drives
- More Integration
  - Self Protection & Diagnostics
- Lower Inductance

SiC Device Research

- **Advantages**
  - High Frequency Operation
  - Less Switching Losses
  - Higher Blocking Voltages
  - Higher Operating Temperature
- **Disadvantages**
  - Expensive
  - Limited Current Level
- **Today’s Manufacturers**
  - Cree Inc. and Infineon Technologies (SiC Schottky Diodes)
- **Three Terminal Devices in ~2005**

Source: Power Electronics Technology at the Dawn of the New Millennium – Status & Future

Source: Dr. T. Paul Chow, RPI
Power Electronic Devices (Low Power)

• One of the More Mature Technologies in Power Electronics

• Rapid Power Semiconductor Advances Continue!

• Rapid Advances Result in Opportunities Related to Operating Parameters, Power Capabilities and Packaging
“Intelligent Power” Technology Trends

Source: Mitsubishi Electronics America, Inc.

Minimize: Parasitics & Interconnects
Power Electronic Devices (High Power)

Switching frequency (Hz)
- 50
- 500
- 5000

Power (I x V, MW)
- 5
- 15
- 45

Target Region
- Emitter
- Turn-Off
- Thyristor

SCR
GTO
IGBT
Switching Technologies

Source: Power Electronics Technology at the Dawn of the New Millenium – Status and Future
Converter Controls

Opportunities:
- Digital Signal Processing (DSP)
- Adaptive or Genetic Algorithms
- Advanced Master Controls for Multiple Distributed Inverters
Components, Packaging, & Cooling

- Passive Components: Designers Typically Use Off-the-Shelf Discrete Components
- Packaging is Strongly Influenced by Cooling Needs, Component Layout and Components
- Cooling Technology Has Improved With Better Heat Transfer From the Power Electronics
Manufacturing Technology

- Currently Most Converters Often Rely Heavily on Manual Assembly.
- The Disparity in Sizes and Methods of Interconnection Increase the Cost and Reduce Quality, Flexibility, & Reliability.
- A Next Step Is a System-Driven Design Approach Using Integrated Packaging Techniques and Focused R&D
## Technology Summary

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<th>Technology Feature</th>
<th>Status (low power)</th>
<th>Status (high power)</th>
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<td>1. Power Electronic Devices</td>
<td>Significant Progress</td>
<td>Evolving</td>
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</tbody>
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Major Converter Markets

- **Motor Drives**  Source: Electronic Motor Drives 2001-2005, Drive Research Corporation, August 2001
  - $12.5 Billion Worldwide Market in 2000
  - $19.1 Billion by 2005

  - $7.7 Billion in 2002
  - $9.6 Billion by 2007

- **Uninterruptible Power Supplies**  Source: The 2002 Power Protection Market Intelligence Report, Venture Development Corporation, August 2002
  - $4.5 Billion Worldwide Market in 2001
  - $5.2 Billion by 2006
Major Converter Markets

- **Flywheels**  
  - $110 Million North American Market in 2000  
  - $250 Million by 2005

- **Fuel Cells**  
  - $42 Million North American Market in 2000  
  - $900 Million by 2005

- **Micro-turbines**  
  - $25 Million North American Market in 2000  
  - $500 Million by 2005

- **Inverters for Solar**  
  Source: IEA PVPS T1-11:2002  
  - $264 Million Worldwide Market in 2002  
  - $515 Million Worldwide Market in 2005  
  With 25%/Annum Growth
Converter Cost

- Converter Cost Is Significant (>25% System Cost)
- Average List Price For Inverters Rated 1-5kW is $834.00/kW Source: Inverter prices: Solarbuzz, Inc., March 2003
- Cost Range From $100/kW (UPS) to $1200/kW (Standalone) Has Been Seen
- Manufactures Reluctant to Provide Detail Cost Information
- Market for PV Systems Are Small Compared to UPS or Motor Drives Market
- Cost Comparison Often Apples to Oranges
Inverter Issues

- Little Movement in Cost and Reliability
- Low Manufacturing Volume For Renewable/DER
- Low Profit Margin

**What is Needed**

- Reduce Costs, Improve Reliability
- Develop State-of-art Inverters with Multiple Uses
  Increases Production Volume For Renewables and Distributed Energy Resources
- Improve Controls and Adaptability
- Improve Manufacturability
Technical Challenges

• Apply Advanced Technologies
  – Digital Signal Processing (DSP)
  – Advanced or Made-to-order Power Electronics
  – Advanced Switching Techniques
  – Internal and External Controls

• Improve Packaging and Layout

• Reduce Thermal Stresses
  – Improved Thermal Management
  – Reduce Internal Losses
Institutional Challenges

• Develop Multi-Use Designs (Synergism!)
  – Align With Huge Users of Similar Power Electronics (Motor Drives, Uninterruptible Power Supplies).

• Provide Focused Government-sponsored R&D and Manufacturing Initiatives for Renewable/DER/Storage-Specific Requirements and Controls.

• Require Manufacturing Quality Control, Environmental & Reliability Testing! (HALTs™)
Key Logistics Issues

- Demand for Renewables/DER and Storage Systems Will Not Drive Power Electronics or Silicon Technology Improvements
- Increased Sales Volume, Better Packaging and Manufacturing Techniques Can Reduce Cost and Increase Reliability
- Standardization is Possible for a Core Unit, but Custom Design Flexibility Must be Retained
- Focused Cross Technology R&D Can Be a Win-Win for Technologies and Inverter Manufacturers
Bibliography

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