IGBT Utilization and Life Cycle
With heavy duty load requirements on Electric Rope Shovels

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Outline of presentation

Joy Global – ABB Success Story
Dynamic AC Drives for Electric Rope Shovels
Load cycle and live time requirements
IGBT physics and mining environment
IGBT analysis and continuous improvements
Product quality process
Summary
IGBT AC Drives for Electric Rope Shovels
Joy Global – ABB Success Story
IGBT AC Drives for Electric Rope Shovels

Joy Global – ABB Success Story

Cooperation with P&H / Joy Global / Komatsu

Started 2005

- Demanding requirements for ABB AC Drives
  - ACS800 Mining Drives for heavy duty environment
  - Switchgear enforcement for high shock and vibration
  - One inverter module size R8i for all drives and supply
  - Special Firmware for dynamic load requirements
  - 20 years life cycle requirement

- In operation 75 AC Drives for new Shovels and 8 for retrofit
  - 2 x Premium Supplier Award from Joy Global

Proven Mining Drive solution for extreme conditions
IGBT AC Drives for Electric Rope Shovels

Load cycle and live time requirements

Hoist Power, Torque, Speed / Load Cycle Hoist (40s)

IGBT Power Plate Temperature / Load Cycle Hoist (50s)
IGBT AC Drives for Electric Rope Shovels

Physics and mining environment

IGBT-Modules
EconoPack
FS450R12KE3

Current: 450A
Peak: 900A
Voltage: 690V

Operation temp.: 125°C
Peak temp.: 150°C
IGBT AC Drives for Electric Rope Shovels

Physics and mining environment

IGBT PowerPack for ABB Drives ACS800

Delivered since 2005 in different revisions

- Challenges for heavy duty mining
  - Shock and vibrations
  - Extreme temperatures -40 to +50°C
  - Dynamic load cycle with temperature differences
  - Constant torque operation with current cycling
  - Continuous operation 24h
  - Compound material stressed by different nature

Physics: mechan, thermal, electrical, chemical, radiation
IGBT AC Drives for Electric Rope Shovels
Analysis and continuous improvements

Supplier: Infineon EconoPack™ FS450R17KE3
Transistor + Diode
3 phase module

Transistor and Diode chip elements are connected with bond wires

Principles of expanded bond wires

New is changed bonding wire design and soldering

Result: Bonding wire is flexible to withstand temp cycles and vibration requirements

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Analysis and continuous improvements

EconoPack™ FS450R17KE3
96 power elements for 1 shovel
576 IGBTs per machine

Heatsink after dry-out of thermal interface material

Principles of Thermal Interface Material (TIM)

New TIM as phase shift material, with stencil and specific pattern

Result: no dry out
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Quality process

**ABB 4Q Process Improvements**

Steps to be successful

- **Q1**
  - Various on-site measurements and site surveys
  - Sample analysis by 3rd parties with expert knowledge
- **Q2**
  - Providing the root cause analysis (RCA)
  - Evaluation the RCA with supplier of power components
- **Q3**
  - Identify measures to improve the drive system
  - Implement features in production and existing fleet
- **Q4**
  - Review of failure rate, which became <2% for over 2100 R8i
  - Analysis of improvements after operating over time

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**4Q Process**

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<thead>
<tr>
<th>Q1 - Measure</th>
<th>Q2 - Analyze</th>
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<tbody>
<tr>
<td>Define opportunity Investigate to understand the current state in detail.</td>
<td>Identify and confirm root causes of the problem.</td>
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<tr>
<td>- Goal is to identify and use those process Outputs, metrics that can help to understand when, how and what problem occurred.</td>
<td>- Goal is to find the real root causes for the problem. Eliminating the root causes prevents the problem from occurring again.</td>
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<td>- Or what additional measures do you need to help identify the problem root cause?</td>
<td>- Good root cause analysis is the key to success in any 4Q project.</td>
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<th>Q3 - Improve</th>
<th>Q4 - Sustain</th>
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<td>Maintain the improvements by standardizing the work methods or processes.</td>
<td>Develop, pilot, and implement solutions that eliminate root causes.</td>
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<td>- Goal is to change the process to the new solution piloted in Q3.</td>
<td>- Goal: create and execute pilot actions that will eliminate the root causes.</td>
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<td>- Gains will be sustained by people working to the new process. New metrics may need to be monitored back in Q1 to</td>
<td>- Test the results and decide if the results are good enough to move forward to next quadrant.</td>
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<tr>
<td>- Close the continuous improvement loop.</td>
<td>- Make the changes permanent</td>
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IGBT AC Drives for Electric Rope Shovels
Analysis and continuous improvements

Test stand to check each IGBT before release to installation
Visual inspection
Electrical test
Output waveform scope check

New device for thermal grease application
Precisely given amount in specified pattern

New drying furnace to dry out thermal grease according specification
Precisely laid and dried
Improved heat flow achieved
Internally tested for 100000+ cycles without any leakage signs
IGBT AC Drives for Electric Rope Shovels

Analysis and continuous improvements

ACS800 Drives Firmware DTC (Direct Torque Control)
- Change system control program
- Analysis of load cycle and high torque requirements
- Changing switching frequency at low speed
- Parameter setting to limit switching frequency below 30\% of nominal speed
- Default value switching frequency changed from 2kHz to 1,4kHz
- Low limit of switching frequency reduced from 1,4 kHz to 1kHz

Result: Reduction of peak temperature by 40\%
Setup for 8 R8i inverter module testing

- Ongoing Reliability Test (ORT) since 2013 with samples from the serial production
- Accelerated Life Testing (ALT) simulation of 10 years life time within 16 weeks by higher temp. range and increased number of load cycles
- New equipment on ABB Drives test lab with 2D & 3D x-ray system, Electron Microscope, ultrasonic analyzer

Result: MTBF R8i module = 93 Y (ACS800), 210 Y (ACS880)
IGBT AC Drives for Electric Rope Shovels

Summary

Global fleet of Electric Shovels AC
Number of IGBTs 7000+
Failure rate below 2%
Product life cycle 12 years
Improved lifetime by reduced thermal cycling
Ongoing reliability testing for Drives modules
Established AC Drives Technology in extreme environment