Smart choice for power

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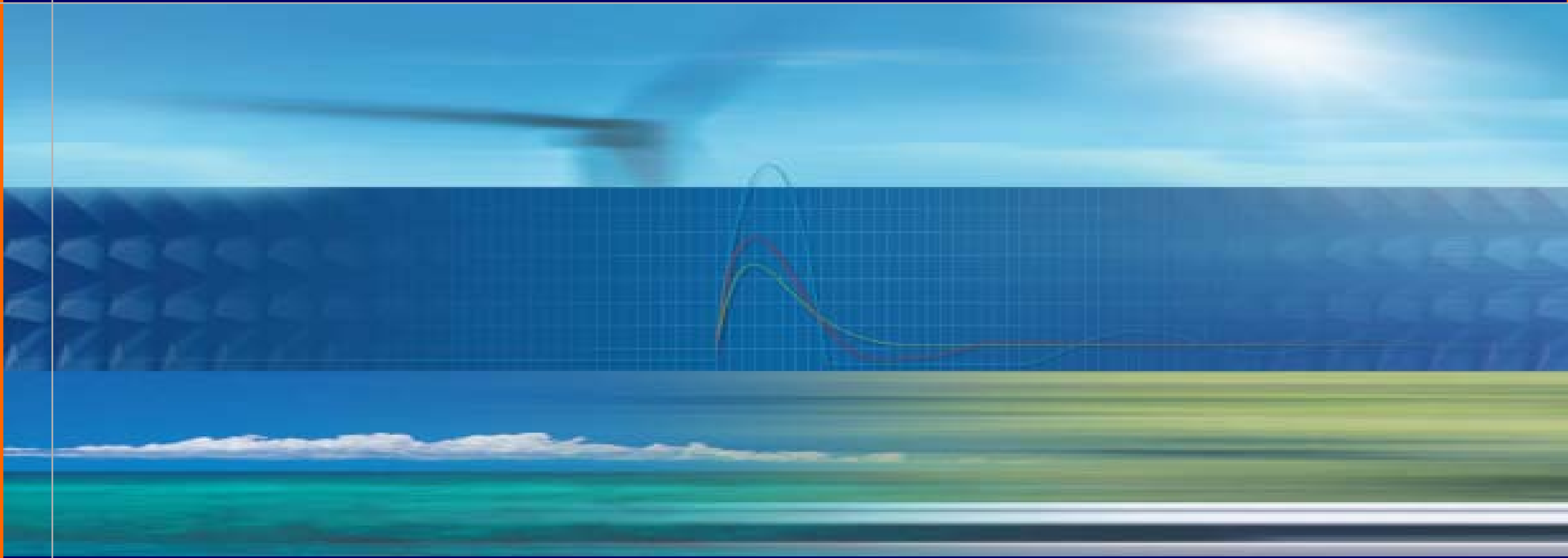

Development of a High Reliability Inverter

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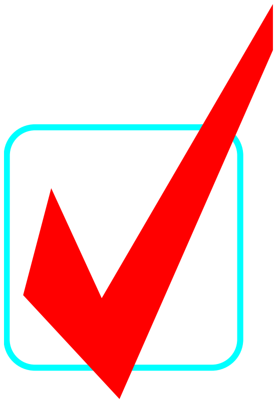
Presentation Overview

- Project goals
- Design concept
- Progress
- MTBF Calculation
- HALT (Highly Accelerated Life Test)
- Results
- Next steps

What is Missing from Today's Inverters



- Higher Reliability
- Higher Efficiency
- Enhanced Communications
- Lower Cost
- Flexibility to support specialized applications

- **Project Objective**:
  - Develop a prototype inverter and charge controller with:

MTBF>10years

Efficiency >94%

Low cost!

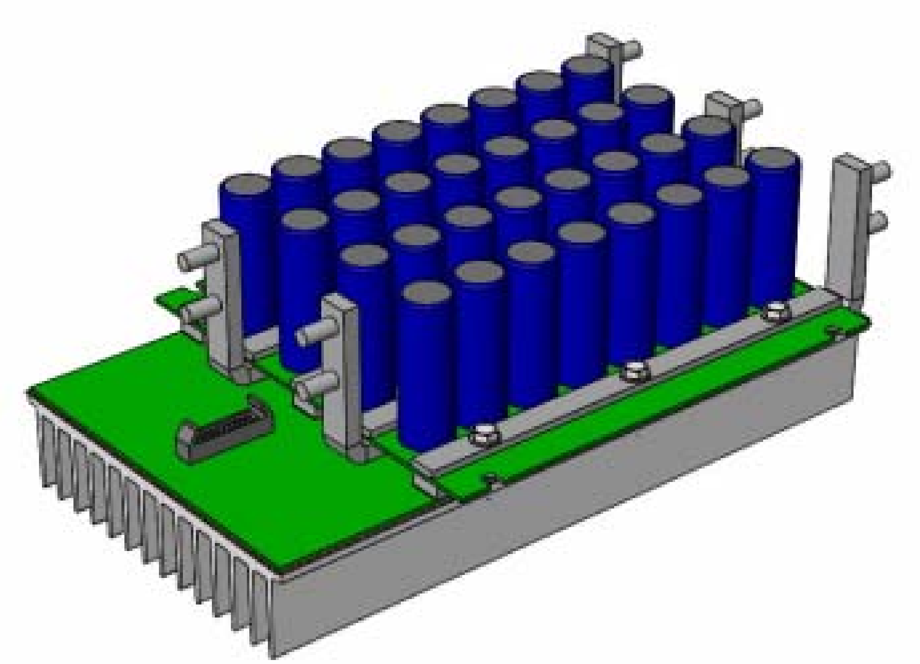
Inverter Design

- Single stage
  - Very high efficiency toroidal transformer
  - High surge capability
  - Simple tap changes for output Voltage configuration
  - Low magnetizing current for reduced tare loss

< 10.8W Core loss

Inverter Design

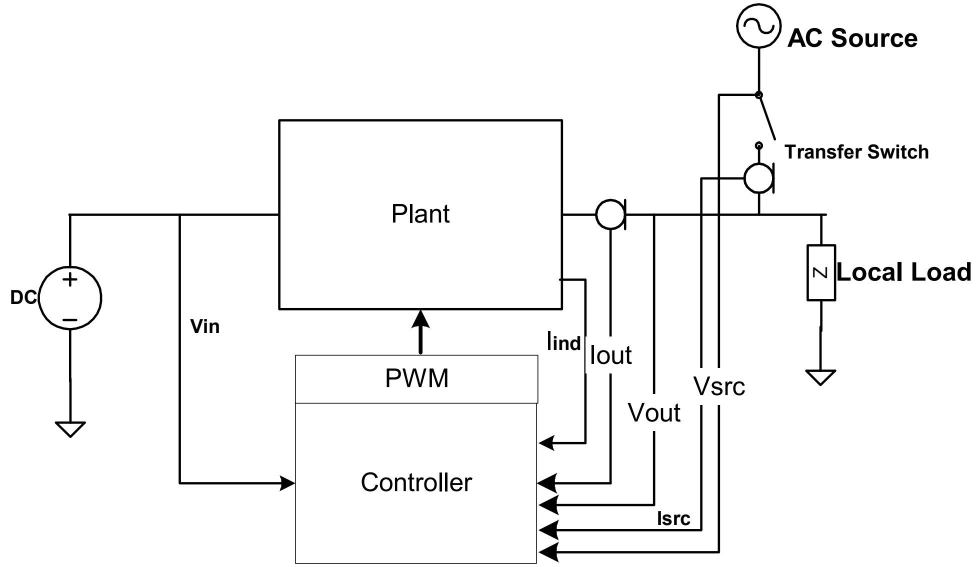
- IMS (Insulated Metal Substrate) Power H-Bridge
  - Rugged solder mounting of MOSFET arrays
  - Minimized thermal resistance from junction to back-plane to heatsink – lower temperature lengthens life
  - Dramatically reduces need for fasteners, in both thermal and electrical paths
  - Reduced assembly time, lower cost
  - Fewer failure modes



IMS Design by Distribute Power CA

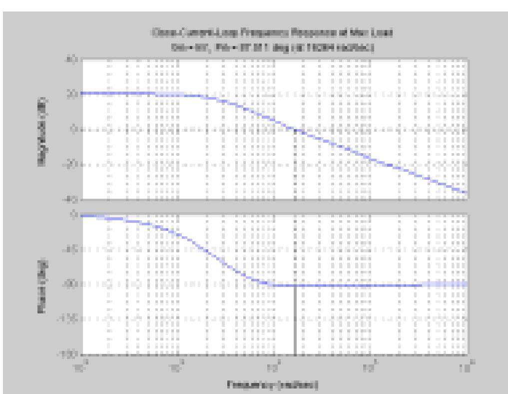
Control Design

- Minimize number of parts for higher reliability
- DSP based with supporting microcontroller
- Direct digital control of H bridge
- Plug and play network support
- Supports charge/invert/grid-tie modes



Progress to date

- "A" model prototypes built and tested
- Verification testing to full load
- HALT on sub-assemblies
- Exceeding efficiency targets



- "B" models designed and fabricated
- Full verification tests underway
- Control loops optimized
- MTBF calculations completed

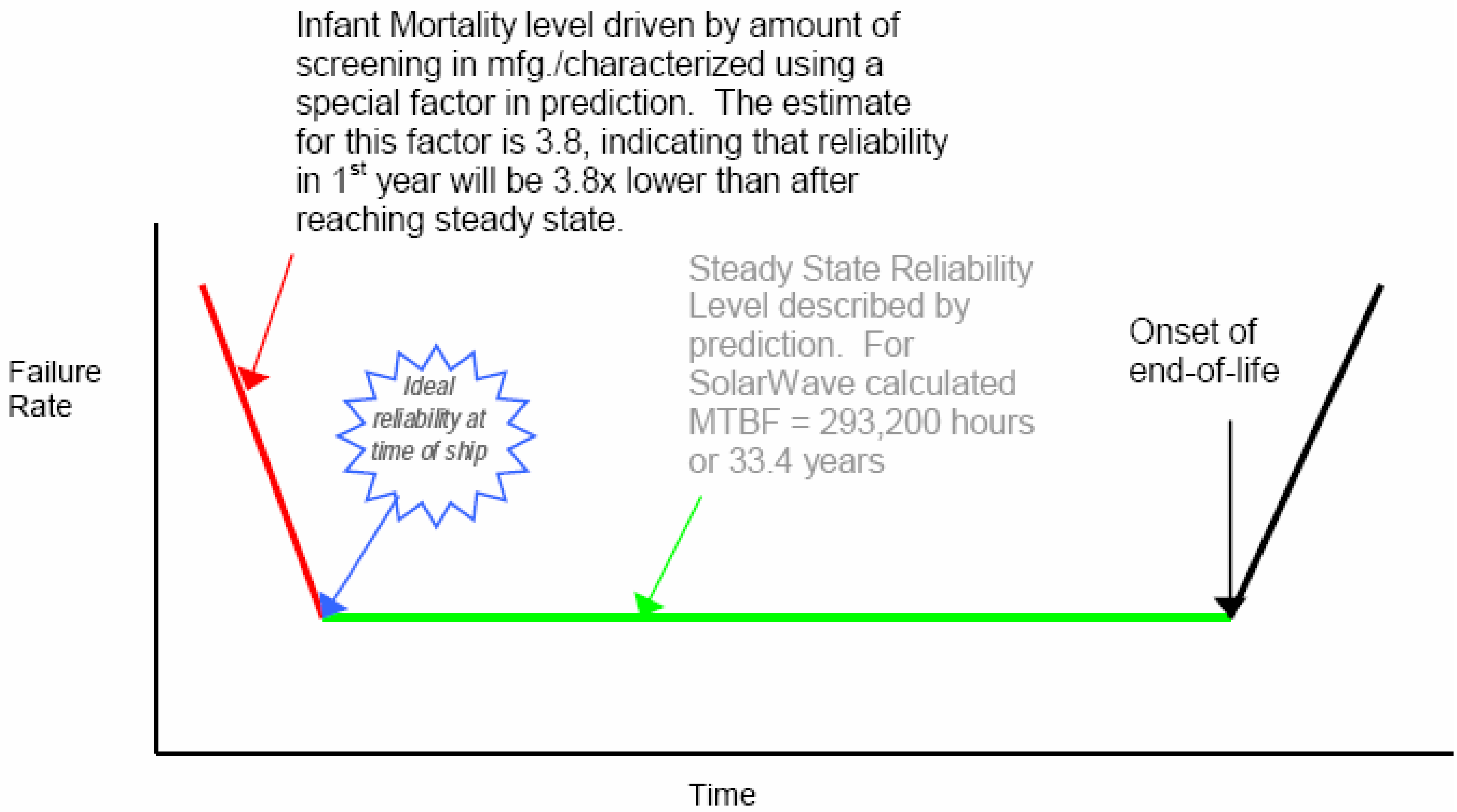
MTBF Results - Inverter

- MOSFET arrays in bridge have dominant failure mode
- Design focused on reducing thermal/electrical stress there
- Fan is a thermally controlled for long life
- Initial reliability can be improved during manufacturing with Highly Accelerated Stress Screen (HASS)

Unit	Predicted MTBF @ relevant Temperatures	
	25°C	40°C
SolarWave	293,200 hours (33.4 years)	163,000 hours (18.6 years)

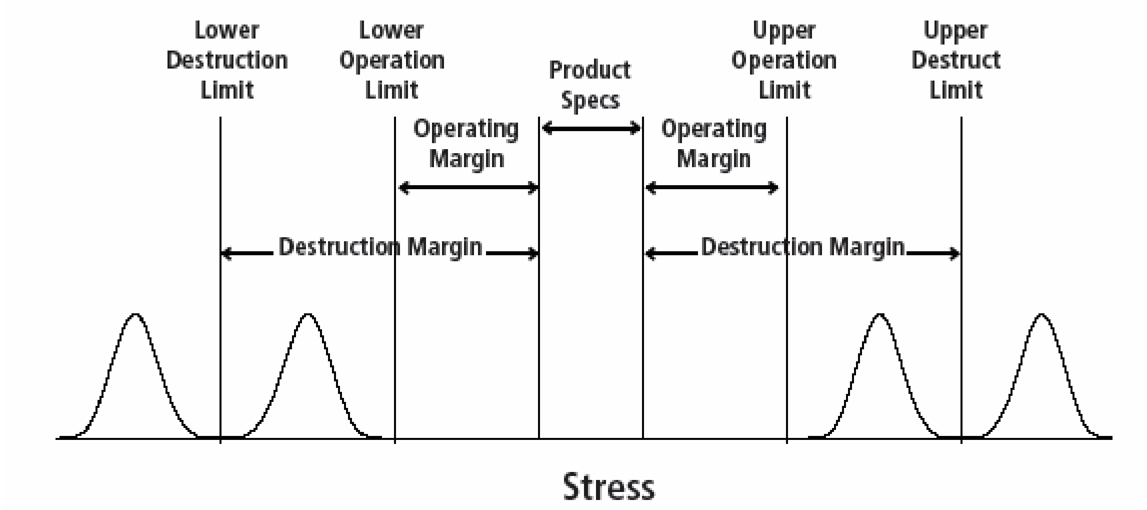
- Using Telcordia SR-332, Issue 1, Parts Stress Method
- 30% utilization factor assumed as typical

MTBF Life Time Estimation



- Highly Accelerated Life Test (HALT) used to find defects and lower field failure rate

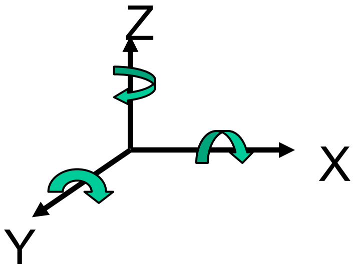
HALT (Highly Accelerated Life Test)



- Find potential failure modes by applying vibrational and thermal stress
- Cycle between destruction limits, verifying operating margins
- HASS (Highly Accelerated Stress Screen) uses reduce levels for production screening

Equipment Used in HALT and HASS

- Liquid nitrogen cooled
  - Rapid thermal transitions
  - -100°C to +200°C range
- Repetitive shock/vibration
  - 6 degrees of freedom
  - 3 axis & 3 rotations simultaneously
  - Broad frequency band (2-10,000Hz)



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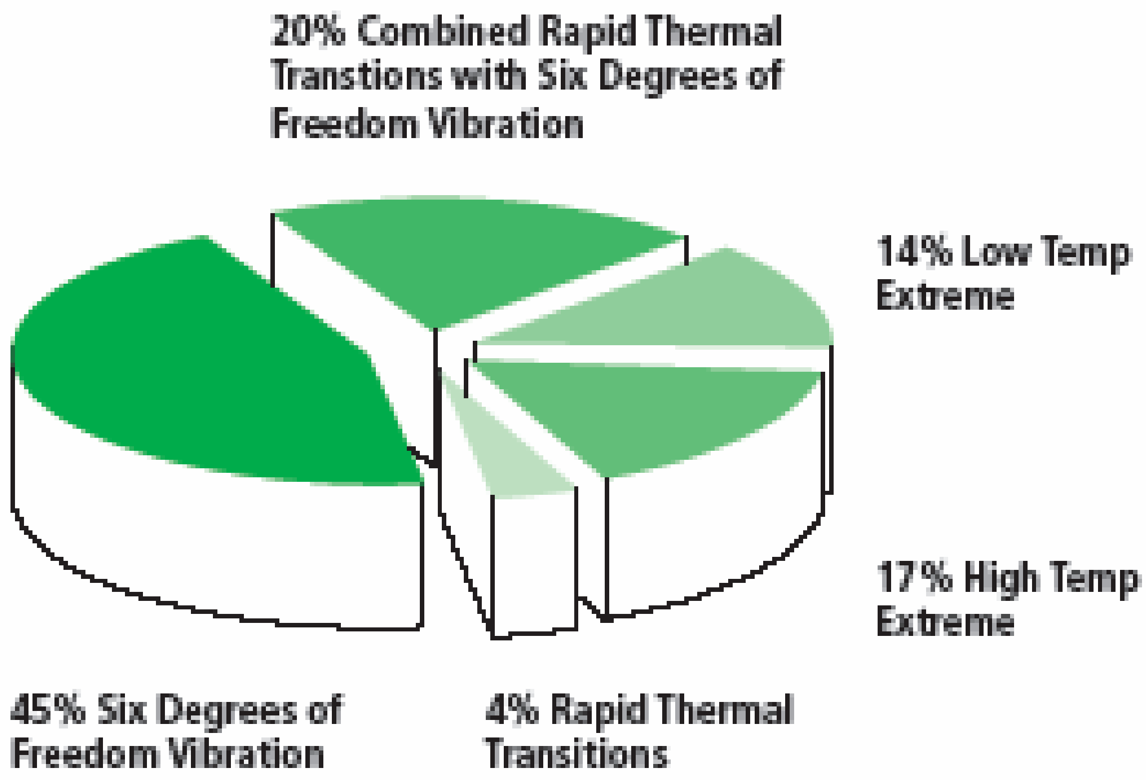
HALT Failures Induced by Stress Environment - typical



- Finds design weaknesses as early in the design cycle as possible

HALT Setup, operational sub-assemblies

- Boards set up without heatsinks and enclosures
- Fully operating
- High volume air flow keeps near constant temperature gradient

HALT Results

- HALT performed on inverter circuit board sub-assemblies
  - Thermal: -70°C to 100°C with 60°C/minute ramp
  - Vibration: up to 32Grms

- At -50°C: Unit would not enter Inverter Mode Increased temperature to -45°C and the unit would cycle through the boot sequence every 8s

  - Changed 47uF electrolytic to tantalum cap, stopped regulator from oscillating due to ESR change

HALT Results

- At +80°C: Unit would fault under load
  - Terminator was not making good connection on interface board
- At -60°C and 28Grms: Over voltage shutdown tripped
  - Software bug
- Several components found susceptible to vibration damage at 30Grms
  - Simple fixes with layout changes or adding RTV

Other design issues

- Several other small issues uncovered during HALT due to inadequate allowance for normal component tolerance
- To be evaluated further with a Design Failure Mode Effects and Criticality Analysis (DFMECA)

Part #	Component	Ref Desig	Qty	Function	Fail Mode or Defect	Local Effect	System Effect	Su	Pu	Du	RPNu	RPN Code	Method of Control	Description of Control or Corrective Action	Pm	Dm	RPNm	RPN Code	Re Ve
034-0825-01	XTAL 4.000MHz Co7pF-MAX SERIES HC49/US SM 100PPM/C -40+85C	Y1 (sheet 1)	1	clock frequency for U1 contoller chip	no clock signal or frequency drift	uController circuit inoperative or intermittent	Unit is completely down	9	3	10	270	2	HALT / Grid Test	HALT performed on product / Grid Test performed	3	4	108	2	HALT Grid T
031-3059-01	MOSFET IRFR120 N-CHAN 100V 7.7A 0.27RDS 210mJ SM TO-252 -55+175C(Tj)	Q7 (sheet 3)	1	Switching control for transformer circuit. Part of Aux Circuit	failed part - no switching	no output signal from transformer T2 T4-5	Unit wont come on (same as T2,4,5)	9	4	10	360	2	HALT / Grid Test	HALT performed on products / Grid Test performed	4	5	180	2	HALT Grid T
0	RES POT 5K MULTITURN 3224 PACKAGE	VR1 (sheet 3)	1	gain adjustment for voltage divider circuit	out of range operation.	U26 circuit inoperative or intermittent	unit inoperative	9	3	10	270	2	HALT / Grid Test	HALT performed on products / Grid Test performed	3	5	135	2	HALT Grid T
035-5007-01	RELAY SPST-NO 20A@100VA C / 10A@200VAC 12VDC UL/ CSA/VDE PC-MT - 40+60C	K1-2 (sheet 4)	2	Switched control of power.	Relay malfunction; open	no output power	no output power	9	4	10	360	2	HALT / Grid Test	HALT performed on products / Grid Test performed	4	4	144	2	HALT Grid T
							Unit shut down												

Results of research

- HALT testing found to be effective in finding design defects and marginal conditions
- Operating stress reduced on key components identified by MTBF calculations
- MTBF estimates indicate design will meet life time goal
- Focus on minimizing power losses have yielded inverter efficiency > 95%

An inverter meeting project Reliability/Efficiency/Cost targets is possible!

Next Steps

- Additional HALT on complete inverter and Charge controller to ensure system robust
- Salt fog test to determine susceptibility to corrosion
- Field test units to validate real world performance
- Complete Process Failure Mode Effects Analysis (PFMEA) to look at potential problems with manufacturing process