Satcon PowerGate Plus
11 Power Ratings Ranging from 30kW-1MW

- **PowerGate Plus**
  - 30 kW
  - DC Input Range: 305-600V

- **PowerGate Plus**
  - 50 kW
  - DC Input Range: 305-600V

- **S-Type**
  - 50 kW
  - DC Input Range: 265-600V

- **PowerGate Plus**
  - 75 kW
  - DC Input Range: 315-600V

- **PowerGate Plus**
  - 100 kW
  - DC Input Range: 315-600V

- **S-Type**
  - 110 kW
  - DC Input Range: 265-600V

- **PowerGate Plus**
  - 135 kW
  - DC Input Range: 310-600V; 320-600V

- **PowerGate Plus**
  - 150 kW
  - DC Input Range: 420-850V

- **PowerGate Plus**
  - 250 kW
  - DC Input Range: 320-600V; 333-600V; 420-850V

- **PowerGate Plus**
  - 500 kW
  - DC Input Range: 320-600V; 333-600V; 420-850V

- **PowerGate Plus**
  - 1 MW
  - DC Input Range: 420-850V

- **PowerGate Plus**
  - 375 kW
  - DC Input Range: 320-600V
Two-piece, pre-engineered MV system for grounded or ungrounded (1MW), 1,000V array:

- 2 x 500kW inverters
- Corresponding MV transformer
- Switchgear
- Simplifies installation connection to an MV grid
- Controlled Environment
• Low installed cost
• NEMA 3R cabinet
• Customizable transformer
  • Any MV configuration
  • Inside or outside Ehouse options

• Fully controllable switchgear connection/disconnection

• Inverter, transformer and switchgear covered by Satcon warranty
Higher efficiencies
- 98.5% Peak | 97.5% CEC
- IP54/NEMA-3R Electronics Enclosure
- Operational temp range best in class: -20°C to +50°C (Optional: +55°C)
- Standard with Equinox:
  - DC combiner fuses
  - CCM Gateway
  - Power factor control
  - Remote start and stop
- Next generation control board
  - Reduced cost and greater availability
  - Real and reactive power control
  - Low voltage ride-thru per BDEW (German conformance)
  - Dynamic VAR capability (CE/NA utility solution)
  - 1000V-rated model has new materials achieves best in class
Hundreds of Millions of Grid Connected kW Hours

- 400+ megawatts total PowerGate shipped
- 220MW of 500 kW since 2005

Highlighted sites:
- General Motors - 12MW
  - Zaragoza Spain
- Southern California Edison - 2MW
  - Fontana California
- GCL - 20MW
  - Xuzhou, China
- First Light - 9MW
  - Ontario Canada
- Energy 21 - 20MW
  - Czech Republic
- CalRENEW – 5MW
  - Fresno, California
- West Pullman - 9MW
  - Chicago, Illinois

1MW Powergate Plus
The new standard for large scale solar power plant production

- Increase system yield by 5-12%
- Deliver more kWh per kW peak of installed capacity
- Reduce installed costs
- Minimize and isolate system downtime
- Prevent, quickly manage and solve energy disruptions over the installation’s lifespan

Reliability Design:
Morphs from
- Low Volume – skilled assemblers
- High Volume – streamlined, Repeatable, manufacturing
Reliability from a Design Perspective
Squeeze Reliability into Design by Reducing FITs

- Reduce Stresses (derate) [Minimize Dissipation First]
- Reduce Component Count
- Eliminate Components
- Alternative Technology
Design Enhancements

- Hermetically sealed
- Modular from 50kW-1MW
- Common components
- Redundant cooling
- High efficiency
- Integrated grid interface & control features
- High reliability
Careful Design of Interconnects – High Infant mortality items

• Interconnects
  – especially between dissimilar items

• Wiring Harnesses
  – Reduce cable assemblies to single parts; testable, replaceable

• Moving Parts
  – Fans, Contactor, Cooling, disconnects, hinges
Load Sharing of high stress devices

• Variable Displacement
  – Shutting down power devices under lower load conditions

• Stress sharing
  – Use history to keep stress equal between redundant power systems
Reliability: Availability
Availability

• Combination of MTTF and MTTR

• MTTF: Constant over time in bottom of bathtub

• MTTR: Establish good service practices
  – Warehouse stocks of common components (Identification)
  – Modular design allows for quick unskilled field replacement
Availability

- Internet connected devices
  - Quick fault reporting
  - Diagnostic information
  - Logging of system parameters prior to fault
- Remote debugging and repair capabilities
- Redundant systems
- Ability to run ‘hobbled’
Availability

• Most Importantly:
  – Able Service Technicians
  – Arrive quickly
  – With knowledge of Exact Problem
  – Parts on Hand
Reliability: Prognostics
Where does this fit?
Prognostics/Diagnostics/Health Monitoring/End of Life Prediction
Insurance vs Assurance?

Historically, Diagnostics & Prognostics have been particularly valuable for Mechanical & Electromechanical Systems (long time scales), based on symptoms, early warning,

- Motors - Brush arcing, bearing vibration, HF vibration
- Power Transformers - Charge, Vibration, Moisture,

Fundamentally, defects + stress => degradation, our focus is wearout, critical assumptions need to hold.
Prognostics

• Relative prediction of critical component usage
• Devices (Thermal): IGBT’s, Capacitors, Reactors
• Mechanical Devices (usage): Breakers, Contactors
• Provide a meaningful metric for preventative maintenance.
Thermal Algorithm for IGBT’s

- Limit sensing (estimation based on models and reduced sensing)
- Monitor life history of the converter with an awareness of the typical aging and wear out mechanisms.
- Insight into failure mechanisms is critical (e.g. sudden $\Delta T$)
- Diffusion related processes vs thermal cycling (fatigue). Accelerated by temperature $T$, change in temperature $\Delta T$, and thermal shock $dT/dt$.

### Reliable/Long Life/Rugged

<table>
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<th>Inherent Weaknesses</th>
<th>External Forces</th>
<th>Internal Forces</th>
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<td>- Temperature</td>
<td>- Power $\rightarrow$ Temperature</td>
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<td>- Aging (FITs)</td>
<td>- Air density</td>
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<td>- Shock/Vibration</td>
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- Examples
  - $\mu$Cracks
  - Metal Migration
  - Diffusion, Filamentation
  - Crystallization
  - Trapped Moisture
  - Plasticizers
  - Conductive Condensation
  - Device Stress
  - Fatigue due to Cycling
  - Thermal Shock $\rightarrow$ Cracks

### Wearout can be Modeled

\[ N_f = 10^{24} \times (0.9354)^{\frac{T - T_0}{T}} \times \left(\frac{\Delta T}{T}\right)^{\frac{1}{1.96}} \]

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Thermal Algorithm for IGBT’s

- Temperature is the all important variable!
- Quick, no history storage for embedded processors (cheap)
- All about mismatches and stress
- Three independent thermal factors:
  - Time at Temp
  - Rate of Temp Change
  - Delta Temp (Cycling)
Predicting “real-usage” life acceleration

Sample Value
Loss due to Time at Temp in Sec
Loss due to Time at Temp

Sample Value
Loss due to Temp Rate in Sec
Loss due to Temp Rate

Sample Value
Loss due DeltaT in Sec
Loss due DeltaT

Sample Value
Remaining life as %
Total % Loss of Life
Real Life thermal cycling – Refine Results
Given a known device stack up, Junction temperatures can be determined.

Sensors placed on a Baseplate give an average thermal picture BUT they don’t capture fast moving events.

Transients cause significant degradation but are un-measurable except through inference.
Mechanical Prognostics

• Simple indicators can help provide immense help in maintain product line.

• Contactors:
  – Total Number of cycles
  – Rapid Cycling

• System Usage Information
  – System uptime/cycles
  – System Thermal history
Goal- Comparative Results

- On a single system, comparative results are as effective as absolute results when it comes to PM and system failure analysis.
- Given a large enough sample size and intelligent accelerated life testing; comparative results can morph into absolute results.
Environmental Issues - Wild card factors