Photovoltaic (PV) Power Systems for Enhancing Energy Security

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E2S2, New Orleans
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Outline

• Demonstration Overview
  – Camp Katuu Site Review
  – Camp Katuu Demonstration Goals

• Development and Design Considerations
  – PV Layout Development
  – Component Selection
     Operating Modes
     Operating Environment
     Availability

• System Options
  – Palau PV System Results
  – Alternative Systems to Enhance Energy Security
Site Review

- Camp Katuu, located near Koror, Palau; latitude of 7° 30’ North
- Remote location
  - Fragile local electrical utility powered by diesel generation
  - High electricity costs
- Corrosive environment
- Abundant sunshine
Demonstration Goals

• Camp Katuu Installation
  - Increase civil outreach and nation building with Palau Government
  - Reduce environmental footprint at Camp Katuu
  - Increase use of alternative energy
  - Demonstrate the feasibility of using alternative energy in the region
  - Quantify PV system performance/capability
  - Train 249th Engineer Battalion to install photovoltaic systems
  - Train Palau Civic Action Team to operate and maintain system
  - Validate camp electrical costs reduction

• Future Installations
  - Leverage design aspects for other remote installations (grid frequency and voltage regulation, corrosion, high electricity costs)
  - Next generation to include off-grid operation capability with energy storage
PV Layout Development

• Sustainability Considerations
  – Safety, maintenance, and reliability
  – Access ways for installation, maintenance, repair

• Performance
  – Simple, intuitive, and robust installation
  – Reliability and electrical costs reduction
  – Roof mounting maximizes capability given limited camp footprint

Camp Katuu Builder’s Shop – PV Array Installation Location
PV Layout Development (cont.)

- PV System Layout Options Considered
PV Layout Development (cont.)

- PV System Layout Considerations and Comparisons

<table>
<thead>
<tr>
<th>No.</th>
<th>Consideration</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
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<tbody>
<tr>
<td>1</td>
<td>Amount of rail mounting (lf)</td>
<td>1440'</td>
<td>1800'</td>
<td>1800'</td>
<td>1440'</td>
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<tr>
<td>2</td>
<td>Ease of rail installation</td>
<td>some rail cutting required to clear walkway</td>
<td>requires two level rail mounting system</td>
<td>requires two level rail mounting system</td>
<td>no rail cutting required</td>
</tr>
<tr>
<td>3</td>
<td>Ease of wiring</td>
<td>Intuitive circuit pattern</td>
<td>Very Intuitive circuit pattern</td>
<td>Very Intuitive circuit pattern</td>
<td>odd circuit pattern</td>
</tr>
<tr>
<td>4</td>
<td>Maintenance access</td>
<td>21&quot; horizontal &amp; vertical walkway, does not have direct access to all panels</td>
<td>Accessible with 15&quot; walkways</td>
<td>Direct access to each panel and has a center walkway</td>
<td>No direct access to most panels</td>
</tr>
<tr>
<td>5</td>
<td>System DC Rating (kW DC) [1]</td>
<td>42.300</td>
<td>42.300</td>
<td>39.480</td>
<td>50.760</td>
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<tr>
<td>6</td>
<td>System AC rating (kW AC) [2]</td>
<td>32.571</td>
<td>32.571</td>
<td>30.400</td>
<td>39.085</td>
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<tr>
<td>7</td>
<td>Fall Protection System</td>
<td>accomodates rail system</td>
<td>accomodates rail system</td>
<td>accomodates rail system</td>
<td>does not accommodate rail system</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Color Legend
- most favorable
- more favorable
- more favorable
- least favorable

Note [1] System DC Rating based upon use of 235W solar panels
Note [2] System AC Rating based upon typical .77 conversion factor from DC power to AC power
PV Layout Selected – Option 1

- Easiest to Implement and Sustain
  - Safety rails
  - Access ways (beginning to be required)
  - Intuitive circuitry/wiring

- Performance
  - Met power requirements

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</table>

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- least favorable
Component Selection

PV Module

Key Features
- Top ranked PVUSA (PTC) rating in California for higher energy production
- 6 years product warranty (materials and workmanship)
- 25 years module power output warranty
- Industry leading plus only power tolerance: +5W (+2%)
- Strong framed module, passing mechanical load test of 5400Pa to withstand heavier snowload
- Ultra reliable in corrosive atmosphere, verified by IEC61701 “Salt Mist Corrosion Testing”
- The 1st manufacturer in the PV industry certified for ISO:TS16949 (The automotive quality management system) in module production since 2003
- ISO 17025 qualified manufacturer owned testing lab, fully complying to IEC, TUV, UL testing standards

Applications
- On-grid residential rooftop
- On-grid commercial/industrial rooftop
- Solar power stations
- Other on-grid applications

Quality Certificates
- IEC 61215, IEC 61730, IEC 61701, UL 1703, CEC Listed, CE, KEMCO and MCS
- ISO9001: 2008: Standards for quality management systems
- ISO/TS16949:2009: The automotive quality management system
- QC080000 HSPM: The Certification for Hazardous Substances Regulations

Best value ($/watt)
Tested for corrosion
Stock item
Common Attributes!!

<table>
<thead>
<tr>
<th>PV Module Specifications</th>
<th>Canadian Solar CS6P-235P</th>
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</thead>
<tbody>
<tr>
<td>Mechanical Attributes</td>
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<tr>
<td>Length (in)</td>
<td>64.5</td>
</tr>
<tr>
<td>Width (in)</td>
<td>38.7</td>
</tr>
<tr>
<td>Thickness (in)</td>
<td>1.57</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>44.1</td>
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<tr>
<td>Electrical Attributes [1]</td>
<td></td>
</tr>
<tr>
<td>Nominal Maximum Power Output at STC (Pmax)</td>
<td>235 Watts</td>
</tr>
<tr>
<td>Voltage at Pmax (Vmp)</td>
<td>29.8 Volts</td>
</tr>
<tr>
<td>Current at Pmax (Imp)</td>
<td>7.9 Amps</td>
</tr>
<tr>
<td>Open Circuit Voltage (Voc)</td>
<td>36.9 Volts</td>
</tr>
<tr>
<td>Short Circuit Current (Isc)</td>
<td>8.09 Amps</td>
</tr>
</tbody>
</table>

[1] Standard Test Conditions for panel ratings: 1,000 Watts/M², AM 1.5, 25 C
Component Selection

Inverter

- Six SMA 7000US inverters for grid-tied system
- Reliable product
- Very low maintenance
- Rated for outdoors use
- Simple, informative interface
- Integral DC disconnect
- Stock item
- Can accommodate electricity grids with poor voltage and frequency regulation
Component Compatibility

**Issue** – Utility upper operating frequency range exceeds inverter default settings; *nuisance trips will occur!!*

**Solution** – Increase inverter operating frequency range based upon electrical utility operations and input

Default Frequency Operating Range is not compatible
Camp Katuu Results

• Installed by 249th Engineering Battallion (Prime Power) and Camp Katuu Civic Action Team
  – All wiring correct per installation drawings
  – Very quick commissioning

• System Reliability During 6 Month Sustainment Period:
  – No failures or repairs
  – System automatically restarted after each grid outage
Camp Katuu Results (cont.)

- **System Performance During 6 Month Sustainment Period:**
  - *Electrical cost savings exceeded estimates by*
    - **Adjusted:** 17% ($25.5k versus $21.8k annually)
    - **Actual:** 10% ($23.9k versus $21.8k annually)
  - *Production met expectations, given rainy season, achieving 94% of annual estimate (53.9MWh versus 57.9MWh)*
Camp Katuu Results (cont.)

System Performance During 6 Month Sustainment Period:

- **Energy cost estimate without PV array**: $49.8k
- **Energy cost with PV array**: $37.5k
- **Camp energy cost reduction by PV array**: 25%

![Pie chart showing PV System Economic Impact from 8/16/2011 to 2/19/2012]

- **Net Electricity Cost with PV Array**: $37,495.82
- **Potential Economic Benefit**: $12,253.77
- **Cost Avoided by Consuming PV Energy**: $12,184.69
- **Value of Exported PV Energy**: $79.06
System Options

- **Grid - Tied System**
  - **Camp Katuu System**
Alternative Systems to Enhance Energy Security

- Grid - Tied System
  - Key Benefits
    - Simple to install
    - Easy to maintain
    - Reduces electrical costs
    - Grid can serve as a load for exporting excess renewable energy
    - Very sustainable

- Key Considerations
  - Requires grid to operate
  - Very few products compatible with unstable grids
SMA’s Sunny Island

- Major Components:
  - Battery bank w/ monitoring
  - Sunny Island

- Can be configured to accept a generator input or utility
SMA’s Sunny Island

• Island System - SMA
  – Leverages multiple energy sources
    ➢ Wind, solar
    ➢ Battery bank
    ➢ Generator or utility
  
  – Key Considerations
    ➢ Not intended for export
    ➢ Number of components to build system
    ➢ Desired system voltage:
      o Single phase 120/240VAC
      o Three phase 120/208, 277/480
Outback’s Radian Inverter

PV Array → Charge Controller → DC Bus → DC Charge/Discharge → Critical Loads

Energy Storage

AC Generator

Utility Source
System Options

• Hybrid System - Outback
  – Leverages Multiple Energy Sources
    ➢ Solar
    ➢ Battery bank, bi-directional
    ➢ Generator
    ➢ Utility
    ➢ Can export

  – Key Considerations
    ➢ Must meet UL1741 for export
    ➢ 120/240 VAC rated system
Summary

- Power Systems to Enhance Energy Security Include:
  - Grid - Tied: simple, few components, no off-grid support
  - Off - Grid: simple, more components than off-grid, requires energy storage
  - Hybrid Systems: few options, but can leverage numerous energy resources to achieve energy security
Questions?

Palau PV System Ribbon Cutting Ceremony Celebrating: 
*
* Nation building through the successful implementation of renewable energy systems

Left to right: Ambassador Helen Reed-Rowe, SFC Daniel Husak, 1st Lt Melissa Jumper, LCDR Grant Watanabe, Clark Boriack (CTC Technical Lead)
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