IMPLEMENTATION OF SUSTAINABLE ENERGY TECHNOLOGIES IN DEVELOPING COUNTRIES – BEST PRACTICES AND LESSONS LEARNED

L3EAP – “Renewable Energy & energy efficiency in Small Island Developing states and beyond”
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MOTIVATION: WHY DO WE TALK ABOUT RENEWABLES INTEGRATION?

Diesel Gensets are a common power supply in developing countries without sufficient grid infrastructure.

The cost advantage of PV-Diesel hybrid systems compared to conventional Diesel Gensets will become even more dominant in the future!

Source: SMA
INTRODUCTION TO SMA GROUP

Global market leader for PV inverters, > 40 GW cumulated installed base
- Founded in 1981
- > 800 Mio. € revenue in 2014
- > 4000 employees globally
- 20 subsidiaries worldwide

SMA Sunbelt Energy GmbH is the Off-Grid/Hybrid expert within the SMA group.

1: Engineering, Procurement, Construction Management; 2: Operation and Maintenance together with local subcontractors
AGENDA

1. Renewable integration in developing countries
   - Technical solutions
   - Best practice and lessons learned
   - Tokelau: 100% integration of solar PV
VAST SOLAR RESOURCES MEET HIGH DIESEL PRICES

Focus markets
- Caribbean
- Indonesia/Malaysia
- Sub-saharan Africa
- Central America
- South America
- Australia

Annual global solar irradiation

Worldwide diesel prices

Source: SMA
There are many different applications for PV-diesel hybrid systems

Focus of this presentation

- Remote electrification (islands) (e.g. Caribbean or Oceania)
- Tourism (e.g. hotels, resorts)
- Utilities/IPP (in off-grid/weak-grid regions)
- Real estate (e.g. offices, warehouses)
- Military (e.g. off-camps, training facilities, military base power plants)
- Rural electrification (in off-grid/weak-grid regions)
- Heavy industries (e.g. mining, oil & gas)
- Big Agriculture (e.g. irrigation systems, farms)
- Remote hospitals (in off-grid/weak-grid regions)
- Remote industries (in off-grid/weak-grid regions)
- Telecom industries and remote pumps (in off-grid/weak-grid regions)
- Rental power

Source: SMA
AGENDA

1. Renewable integration in developing countries
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3. Best practice and lessons learned
4. Tokelau: 100% integration of solar PV
DEPENDING ON APPLICATION, SYSTEM SIZE AND SYSTEM TOPOLOGY, WE FIND TWO MAIN CASES

**Genset builds up the grid (PV as “slave”)**

- Several 100kW – multi MW
- Reducing OPEX (fuel saving)
- PPA structures

**Battery inverter builds up the grid (PV + storage as „master”, Genset supporting unit)**

- Up to several 100 kW
- Rural electrif./reduction of power outages
- Governmental tenders + owned assets

Source: SMA
INDUSTRIAL LOADS IN REMOTE AREAS: TYPICALLY SUPPLIED BY CONVENTIONAL GENSET SYSTEMS

Powerhouse
Includes main busbars, genset controllers, etc.

Genset System
The main component in the electricity supply system

Industrial Load
e.g. Mining facility, cement factory, metal works
ADDING PHOTOVOLTAICS IS THE FIRST STEP TOWARDS A FUTURE-PROOF SYSTEM...

1. Balance of System (e.g. cabling, module racks, etc)  
Source: SMA

PV inverter
The heart of SMA’s solution for hybrid systems

PV Modules/BOS
All module technologies supported

Genset System
The main component in the electricity supply system

Industrial Load
e.g. Mining facility, cement factory, metal works

Powerhouse
Includes main busbars, genset controllers, etc.
SMART COMMUNICATION BETWEEN GENSET AND PV: MANDATORY TO LEVERAGE THE FULL HYBRID POTENTIAL

1. Balance of System (e.g. cabling, module racks, etc)  
2. Data Acquisition Module  
   Measures the actual load both active and reactive

PV inverter  
The heart of SMA’s solution for hybrid systems

PV Modules/BOS1  
All module technologies supported

Interface Module  
Acts as a data concentrator and data logging device for Sunny Tripower inverters

PV Main Controller Module  
Monitors genset status and computes maximum allowed PV power

Powerhouse  
Includes main busbars, genset controllers, etc.

Industrial Load  
e.g. Mining facility, cement factory, metal works

Genset System  
The main component in the electricity supply system

---

1. Source: SMA
INTEGRATION OF STORAGE SMOOTHENS THE ELECTRICITY SUPPLY AND INCREASES PV PENETRATION

**PV Modules/BOS**: All module technologies supported

**PV inverter**: The heart of SMA’s solution for hybrid systems

**Interface Module**: Acts as a data concentrator and data logging device for Sunny Tripower inverters

**Data Acquisition Module**: Measures the actual load both active and reactive

**PV Main Controller Module**: Monitors genset status and computes maximum allowed PV power

**Battery Inverter**: (optional, for increased PV penetration)

**Industrial Load**: e.g. Mining facility, cement factory, metal works

**Powerhouse**: Includes main busbars, genset controllers, etc.

**Genset System**: The main component in the electricity supply system

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1. Balance of System (e.g. cabling, module racks, etc)

Source: SMA
OFF-GRID AND BACKUP SYSTEMS WITH GRID-BUILDING INVERTERS

Backup System and Solar Power

- Battery inverter with grid-forming capability (in case of public grid failure)
- PV array and PV inverter supply the stand-alone grid (AC-coupled) with electricity
- Battery system for energy storage

Source: SMA
APPLICATION EXAMPLES – „PEAK SHAVING“

- Load > PV power
- Grid available

Many electricity tariffs charge extra cost for peak supply!

Source: SMA
Net Metering very attractive under many electricity tariff schemes!

Source: SMA
APPLICATION EXAMPLES – „BACKUP CASE“

- Load < PV power or vice versa
- Grid not available

Avoidance of power outages help bringing down opportunity cost significantly!

Source: SMA
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3. Best practice and lessons learned

4. Tokelau: 100% integration of solar PV
SMOOTH INTERACTION BETWEEN PV, GRID AND GENSET IS MANDATORY

1. Sunrise
2. Drop of PV power (clouds)
3. Grid failure, start of genset
4. PV covers load changes
5. Genset compensate cloud effect
6. Grid back again, PV synchronizes

Source: SMA project example
MAKE SURE YOUR EQUIPMENT MEETS HARSH ENVIRONMENT REQUIREMENTS – EXAMPLE IP CLASS

„I don’t need a fancy IP 54 device. I am fine with IP 20¹ or 21².”

„OK, but what does IP 20/21 mean?”

IP X Y

1. Digit: Solid particle protection

<table>
<thead>
<tr>
<th>Level</th>
<th>Object size protected against</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>&gt; 50 mm</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 12.5 mm</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 2.5 mm</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 1 mm</td>
</tr>
<tr>
<td>5</td>
<td>Dust protected</td>
</tr>
</tbody>
</table>

2. Digit: Liquid ingress protection

<table>
<thead>
<tr>
<th>Level</th>
<th>Protected against</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>1</td>
<td>Dripping water</td>
</tr>
<tr>
<td>2</td>
<td>Dripping water @15° tilt angle</td>
</tr>
<tr>
<td>3</td>
<td>Spraying water</td>
</tr>
<tr>
<td>4</td>
<td>Splashing of water</td>
</tr>
</tbody>
</table>

Equivalent to:

- 1 litre of rainfall per minute per m²
- 3 litres of rainfall per minute per m²
- 0.7 litres/minute @ 100 kPA
- 10 litres/minute @ 100 kPA

“The IP Code, International Protection Marking, IEC standard 60529, classifies and rates the degree of protection provided against intrusion (body parts such as hands and fingers), dust, accidental contact, and water by mechanical casings and electrical enclosures. It is published by the International Electrotechnical Commission (IEC).”

Source: IEC, SMA
Best practice

IP PROTECTION CLASS – IMPORTANT IN HARSH ENVIRONMENTS

“Would your IP 21 inverter have survived this?”

“OK, but my installation is inhouse.”

“Well, good luck then...”

Source: SMA reference examples
# Things to Remember for Off-Grid Systems and Renewable Integration

<table>
<thead>
<tr>
<th>Fact</th>
<th>Consequence / ToDo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mini-Grids are not as stable as large public grids</td>
<td>Smooth interaction/communication between loads, renewables, and backup source (e.g. Diesel Genset) need to be secured</td>
</tr>
<tr>
<td>Most Off-Grid systems are in harsh environments (dust, salt, water, temperature...)</td>
<td>High IP protection class for all electrical devices (+ over-voltage and short-circuit protection...)</td>
</tr>
<tr>
<td>Off-Grid systems may be complex; e.g. customers sometimes ask for a combination Wind+PV+Hydro+Storage</td>
<td>Reduce complexity: start with integration of just one renewable energy source and subsequently expand the system, if required</td>
</tr>
<tr>
<td>Consumption behavior may change</td>
<td>Go for a scalable solution</td>
</tr>
<tr>
<td>Off-Grid systems are remote (by definition)</td>
<td>Collaborate with local partners for Service and Maintenance</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
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3. Best practice and lessons learned
4. Tokelau: 100% integration of solar PV
Tokelau is first country globally with 100% solar PV supply!

- 1 MW PV (4032 PV modules, 205 SMA Sunny Boy Inverters)
- 8 MWh storage system (1,344 batteries, 93 SMA Sunny Islands + 121 Sunny Island Chargers)
- Zero CO₂ emissions!
THANK YOU FOR YOUR ATTENTION!

Contact for further questions

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