Disclaimer

This presentation may contain future predictions. Future predictions are statements that do not describe facts from the past. They also contain assessments on our assumptions and expectations. These assessments are based on planning, estimates, and forecasts, which are currently available to the SMA Solar Technology AG (SMA or company) board of directors. Future predictions are therefore only applicable on the day on which they are made. It lies in the nature of future predictions that they contain risks and elements of uncertainty. Various known and unknown risks, uncertainties, and other factors may cause the actual results, financial situation, development, or performance of the company to significantly deviate from the assessments provided in this presentation. These factors include those that SMA has described in published reports, which are available on the website www.SMA.de. The company assumes no liability for updating or adjusting such future predictions in accordance with future events or developments.

This presentation serves informational purposes only and does not constitute an offer or request to buy, keep, or sell company shares.
The inverter is the “heart” of every PV system

Visual representation of a PV System

Inverters are “high-tech products”: The computing power of the seven microprocessors alone is comparable to that of a notebook
SMA Solar Technology

- Founded in 1981
- Headquarters in Niestetal, Germany
- Publicly Traded on the Frankfurt Exchange
- Eighteen Subsidiaries on Four Continents
- More than 5,000 Employees
- Over 600 R&D Engineers
- Strong Balance Sheet
- Over 50% of Revenue Outside of Germany
- Ranked Best Inverter Company by Photon
- Ranked 2nd Best Solar Company in EU
- Top Awards in Product Innovations
World Leader In Installed Capacity

Cumulative PV Installed Capacity (MW)

Yearly SMA PV Installed Capacity (MW)

Yearly Sales in Million $

Yearly % Market Share
World Leader In Manufacturing Capacity

- 200,000 ft² of Manufacturing Space
- Best in Class Quality Control
- 12GW Capacity
- CO₂ Neutral Factory
- Build to Order Process
- ISO 9001 Certification
N.A Leader In Manufacturing Capacity

- US Plant in Denver, CO
- 1GW Production Capacity (World’s 2nd Largest)
- Over 700 US Jobs Created
- Fully Compliant with ARRA
- Flex Production Lines

- Ontario Factory with Contract Manufacturing Partner
- Fully Compliant with Ontario Content
- Direct & Indirect Jobs for Ontario

» New NA factories will increase flexibility to serve fast growing US & ON markets
World Leader in Utility Scale Projects

SUNNY CENTRAL
- Energy park Waldpolenz
  Brandis, Germany
- 40 MWp
- 72 x Sunny Central 500HE
## North America Leader in Utility Scale Projects

<table>
<thead>
<tr>
<th>Location</th>
<th>Country</th>
<th>Plant Size</th>
<th>Inverters</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memphis, TN</td>
<td>USA</td>
<td>5 MW</td>
<td>10 SMA 500 kVA</td>
<td>Construction</td>
</tr>
<tr>
<td>Tilbury, ON</td>
<td>Canada</td>
<td>5 MW</td>
<td>10 SMA 500 kVA</td>
<td>Completed</td>
</tr>
<tr>
<td>Ridgeland, ON</td>
<td>Canada</td>
<td>9 MW</td>
<td>17 SMA 500 kVA</td>
<td>Construction</td>
</tr>
<tr>
<td>Wyandot, OH</td>
<td>USA</td>
<td>10 MW</td>
<td>16 SMA 630 kVA</td>
<td>Completed</td>
</tr>
<tr>
<td>Jacksonville, FL</td>
<td>USA</td>
<td>13 MW</td>
<td>20 SMA 630 kVA</td>
<td>Completed</td>
</tr>
<tr>
<td>San Antonio, TX</td>
<td>USA</td>
<td>14 MW</td>
<td>22 SMA 630 kVA</td>
<td>Completed</td>
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<tr>
<td>Alamosa, CO</td>
<td>USA</td>
<td>19 MW</td>
<td>38 SMA 500 kVA</td>
<td>Completed</td>
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<tr>
<td>Santa Teresa, NM</td>
<td>USA</td>
<td>20 MW</td>
<td>32 SMA 630 kVA</td>
<td>Construction</td>
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<tr>
<td>Cimarron, NM</td>
<td>USA</td>
<td>30 MW</td>
<td>48 SMA 630 kVA</td>
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<tr>
<td>Brookhaven, NY</td>
<td>USA</td>
<td>32 MW</td>
<td>50 SMA 630 kVA</td>
<td>Construction</td>
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<tr>
<td>Sarnia, ON</td>
<td>Canada</td>
<td>60 MW</td>
<td>120 SMA 500 kVA</td>
<td>Completed</td>
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</table>
Sunny Boy/Sunny TriPower

Max. AC Power (W)

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<th>11</th>
<th>17</th>
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<tbody>
<tr>
<td>1200</td>
<td>1700</td>
<td>2500</td>
<td>3000</td>
<td>3300</td>
<td>4600A</td>
<td>5000A</td>
<td>6000A</td>
<td>7000HV</td>
</tr>
<tr>
<td>2000HF</td>
<td>2500HF</td>
<td>3000HF</td>
<td>3300HF</td>
<td>4600A</td>
<td>5000A</td>
<td>6000A</td>
<td>7000HV-11</td>
<td></td>
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<tr>
<td>2100TL</td>
<td>3300TL HC</td>
<td>3000TL</td>
<td>4000TL</td>
<td>5000TL</td>
<td>6000TL</td>
<td>7000TL</td>
<td>8000US</td>
<td></td>
</tr>
<tr>
<td>2000HF</td>
<td>2500HF</td>
<td>3000HF</td>
<td>3300HF</td>
<td>4600A</td>
<td>5000A</td>
<td>6000A</td>
<td>7000HV-11</td>
<td></td>
</tr>
<tr>
<td>UL-Listed</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>With Transformer</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Without Transformer</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some Facts about Germany

| Geographic Size | 357,021 km²  
Slightly smaller than Montana (376,55 km² ) |
|----------------|------------------------------------------------|
| Population     | 81.8 million  
Most populous country in EU |
| Installed Wind Capacity (2010) | ~ 27.2 GW (3rd behind China @ 41.8GW & US @ 40.2GW)  
37.5 TWh or 6.5% of Generation  
World’s Largest |
| Installed Solar Capacity (2010) | ~ 17GW  
12 TWh, 2% of Generation  
World’s largest |
| Renewable Penetration (2010)  
(Wind, Solar, Hydro, Biomass) | ~ 102 TWh representing 17% of Electricity Consumption  
World’s Largest |
| Cost to Support Solar | 5% increase in average electricity bill |
| Solar Industry Economic Impact | >200,000 direct jobs related to PV |

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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</thead>
<tbody>
<tr>
<td>Solar PV Capacity (MW)</td>
<td>186</td>
<td>296</td>
<td>439</td>
<td>1,074</td>
<td>1,980</td>
<td>2,812</td>
<td>3,977</td>
<td>5,877</td>
<td>8,877</td>
<td>17,251</td>
</tr>
<tr>
<td>PV Generation (GWh)</td>
<td>76</td>
<td>162</td>
<td>313</td>
<td>556</td>
<td>1,282</td>
<td>2,220</td>
<td>3,075</td>
<td>4,420</td>
<td>6,200</td>
<td>12,000</td>
</tr>
<tr>
<td>PV % of total electricity consumption</td>
<td>0.7</td>
<td>1.1</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Recent German Energy Policy Announcements

In September 2010 the German Government announced a new aggressive energy policy with the following targets:

- Reducing CO₂ emissions 40% below 1990 levels by 2020 and 80% below 1990 levels by 2050
- Increasing the relative share of renewable energy in gross energy consumption to 18% by 2020, 30% by 2030 and 60% by 2050
- Increasing the relative share of renewable energy in gross electrical consumption to 35% by 2020 and 80% by 2050
- Increasing the national energy efficiency by cutting electrical consumption 50% below 2008 levels by 2050
Germany is the highest consumer of solar energy in the world
Solar Resources: US vs. Germany
Solar Resources: Canada
Solar PV for Utilities: Pros and Cons

**Market Forces/Drivers**
- Growing Support for Renewable Energy
- State RPS Policies – 1/3 for CA
- ITC Extended to Utilities – Uncapped
- Smart Grid Infrastructure: Sporadic DG Improves Grid Reliability
- Smart Grid Infrastructure: DG One Solution to Transmission Congestion
- Smart Grid Infrastructure: DG Load Serving Cuts Power Losses
- Unlike Wind, Solar Correlates better with Load Demand
- Loss of Customers to Emerging Solar Utilities
- Sun Shot initiative driving cost down to grid parity ($1/watt installed)

**Market Threats/Risks**
- Resources still scarce
- Low Natural Gas prices
- PV highest cost in terms of $/MWh for utilities
- Risk Management is Demanding Higher IRR from Investors
- Insufficient Historical Data for Actual Plant(s) Performance(s) Over Extended Period of Time (15 – 20+ years)
- Intermittency Major Issue
- Regulation Against Owning Generation Assets
- Smart Grid Infrastructure: Too Much DG Penetration Effect on Grid Still Unknown
Individual States’ RPS

Renewable Portfolio Standards

www.dsireusa.org / June 2010

29 states + DC have an RPS
(7 states have goals)

State renewable portfolio standard
State renewable portfolio goal
Solar water heating eligible

Minimum solar or customer-sited requirement
Extra credit for solar or customer-sited renewables
† Includes non-renewable alternative resources

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SMA America – Confidential
Source: NERC IVGTF
California average wind and solar output, along with net demand, July 2003
PV Intermittency

PV plant output on a sunny day
(Sampling time 10 seconds)

PV plant output on a partly cloudy day
(Sampling time 10 seconds)

Source: NERC IVGTF Report
Utility Reliability Concerns with PV Plants

<table>
<thead>
<tr>
<th>Inadequate Characteristics</th>
<th>Required Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Not Dispatched</td>
<td>➢ Ability to Dispatch</td>
</tr>
<tr>
<td>➢ Non-Voltage Regulating</td>
<td>➢ Voltage Regulation</td>
</tr>
<tr>
<td>➢ Non-Frequency Responsive</td>
<td>➢ Frequency Response</td>
</tr>
<tr>
<td>➢ Unity Power Factor</td>
<td>➢ Power Factor Control</td>
</tr>
<tr>
<td>➢ Non-Controlled ramp-rate</td>
<td>➢ Ramp-Rate Control</td>
</tr>
<tr>
<td>➢ Trips-off during voltage fluctuations</td>
<td>➢ Ride-Through (LVRT)</td>
</tr>
<tr>
<td>➢ No Stability Models</td>
<td>➢ Stability Models</td>
</tr>
</tbody>
</table>

➢ Currently PV Market “Regulated” by IEEE1547, UL1741
➢ Market Transformation from PV Business to Energy Business
➢ PV Power Plants are becoming generation assets to conventional IPPs and Utilities
➢ Utilities, ISO’s and Reliability Coordinators are applying conventional LGIA standards to PV Plants which present conflicts to IEEE1547 standards.
Integrating Renewable Energy

- **Target:** Maximum possible percentage of electricity from renewable energy sources;
- Phase out fossil and nuclear. EEG law of 2000 grandfathered by Hermann Scheer.
- Generous Feed-In-Tariffs (FIT) for Solar PV
- Force acceptance of PV inverters and guarantee interconnection access.
- PV penetration explodes, mimicking wind
- Situation: Renewable PV generation systems do not contribute to grid stability
- Expert’s opinion: increasing share of renewable sources will require new standards for interconnections
- **SMA first inverter company to be awarded BDEW full compliance with MV Directive**
BDEW* Guidelines Summarized

- Ability to control PV generation to a specified % of nominal power rating (Remote Dispatch)

- Ability to automatically reduce active power with frequency deviations (Over Frequency Response)

- Ability to supply/absorb reactive power during PV operation
  - Ability to Control Power Factor (PF Control Mode)

- Fault Ride-Through (LVRT)
  - Ability to supply reactive current during fault ride-through period

* German Association of Energy and Water Industries (BDEW)
Simplified illustration of grid control using PV plants (medium-voltage grid)

High voltage (e.g. 380 kV)

Medium voltage (e.g. 20 kV)

Dynamic Grid Support
- Internal control of the inverter
- Short Circuit Current
- FRT (fault right through)

Static Grid Support
- Setpoint for reactive power
  (e.g. \( \cos \phi = 0.9 \))
- Limitation of active power

Controller

Grid safety management
- Power limitation
  100/60/30/0 \%  

Source: Erzeugungsanlagen am Mittelspannungsnetz. BDEW, Release June 2008
Grid Support: Active Power Limitation

- Prevent overload or grid congestion
- 4 default settings but configurable up to 16 steps. e.g.:
  - 100 % power
  - 60 % power
  - 30 % power
  - 0 % power
- Ramp Configurable % rate increase vs. % rate decrease from 20sec to 60min
Grid Support: Over Frequency Response

SMA 1000V Inverters Designed for Static and Dynamic Active Power Control

- Reduction of active power dependent on Grid Frequency.
  - in Case of Grid Failures
  - in Case of Power Surplus
  - to avoid Grid Instabilities
- 4% active power reduction / 0.1Hz
- Configurable for 60Hz and various % slopes

\[ \Delta P = 20 \cdot P_M \cdot \frac{50.2 \, \text{Hz} - f_{\text{grid}}}{50 \, \text{Hz}} \]

when \( 50.2 \, \text{Hz} \leq f_{\text{grid}} \leq 51.5 \, \text{Hz} \)

\( P_M \) power currently available
\( \Delta P \) power reduction
\( f_{\text{grid}} \) grid frequency

In the range \( 47.5 \, \text{Hz} \leq f_{\text{grid}} \leq 50.2 \, \text{Hz} \) no restriction
When \( f_{\text{grid}} \leq 47.5 \) and \( f_{\text{Netz}} \geq 51.5 \, \text{Hz} \) disconnection from grid

Source: Erzeugungsanlagen am Mittelspannungsnetz. BDEW, Release June 2008
Grid Support: Reactive Power Requirements

- **Objective**: Maintain stable grid voltage
- **Static (or fixed) power factor** specified by utility
- **Dynamic reactive power** on demand remotely controlled by utility
- **Dynamic reactive power** depending on grid voltage
- **Dynamic power factor** according to a pre-defined schedule

- **BDEW PF Requirement**: 0.95 lagging to 0.95 leading at point of interconnection

> Impact on PV inverter and plant design!

SMA Inverters Comply with PF Control

Source: Erzeugungsanlagen am Mittelspannungsnetz. BDEW, Release June 2008
Sample PV Plant Single Line Diagram

Inverter AC Output
Range {200V - 480V}

MV XFMR

Medium Voltage Bus
Range {12.5kV - 34.5kV}

HV XFMR

POI

Transmission Grid

Transmission Bus \( \geq 69kV \)
Reactive Compensation, Capacitive Example

(MV GSU XFMR) Collector Bus 34.5kV

100MVA 10% Z

POI 115kV

Transmission Grid

100 MW
PF=0.95 Lag
33MVAR
= 105MVA Facility

CB = Circuit Breaker
FD = Fuse Disconnect
SW = Switch

PF=0.90 Lag
MVAR Demand > 33MVAR
VAR Compensation with FACTS Devices

Inverter AC Output 370V

MV XFMR

34.5kV

HV XFMR

POI 115 kV

Transmission Grid

DSTATCOM System
±7.5 MVAR Continuous
±19.8 MVAR Dynamic

6x ±1.25 MVAR DSTATCOM Inverters

Switched Caps or Reactors As Needed Qty 6 Max.

Master Control
Regulate POI Voltage
Inverter Control Cap/Rx Switch PV Q/PF Cmd

Q=0, PF=1 to PV Inverters

PV Inverter Control Interface

SMA America – Confidential
VAR Compensation with Inverters

Inverter AC Output 370V

MV XFMR

34.5kV

HV XFMR

POI 115 kV

Transmission Grid

Q/PF CMD to PV Inverters

Master Control
Regulate POI PF or Voltage

PV Inverter Control Interface
The SMA SC800CP is currently the industry’s largest single inverter. Rated @ 880kVA for T \leq 25°C means: 800kW and ±360kVAR Range.

\[
S = \sqrt{P^2 + Q^2} \quad S = \frac{P}{\cos \phi} \quad P = S \cdot \cos \phi \quad Q = \sqrt{S^2 - P^2}
\]
System Design with Reactive Power Supply

\[ \Delta P = P_{\text{limit}} - P_{\text{max}} \]

\( S_{\text{max}} \)

\( S_{\text{max,ind.}} \)

\( Q_{\text{max,ind.}} \)

\( Q_{\text{max,inductive}} \)

\( Q_{\text{max, capacitive}} \)
Power Factor Value at 0 and 1

If current $i$ and voltage $v$ are in phase, a fluctuating but always positive power results - pure active power.

In the case of a phase shift of 90 degrees between $i$ and $v$, the average value of the power is zero - pure reactive power.
Adjustable Current Angle = Adjustable Power Factor

AC Voltage & Currents

Sync. Voltage

Current, 100%
Current, 60%

Angle phi at which inverter current is imposed into a voltage source

COS phi = Power Factor
Voltage Dependent Power Factor Adjustment

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Relais 4bit</th>
<th>Cos φ</th>
<th>equals Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>90%</td>
<td>1</td>
<td>0.9</td>
<td>43.59%</td>
</tr>
<tr>
<td>96.5%</td>
<td>1</td>
<td>0.9</td>
<td>43.59%</td>
</tr>
<tr>
<td>97.0%</td>
<td>2</td>
<td>0.94</td>
<td>34.12%</td>
</tr>
<tr>
<td>97.5%</td>
<td>3</td>
<td>0.97</td>
<td>24.31%</td>
</tr>
<tr>
<td>98.0%</td>
<td>4</td>
<td>0.99</td>
<td>14.11%</td>
</tr>
<tr>
<td>98.5%</td>
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<td>0.997</td>
<td>7.74%</td>
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<td>1</td>
<td>0.00%</td>
</tr>
<tr>
<td>101.5%</td>
<td>11</td>
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<td>-14.11%</td>
</tr>
<tr>
<td>102.0%</td>
<td>12</td>
<td>0.97</td>
<td>-24.31%</td>
</tr>
<tr>
<td>102.5%</td>
<td>13</td>
<td>0.94</td>
<td>-34.12%</td>
</tr>
<tr>
<td>103.0%</td>
<td>14</td>
<td>0.9</td>
<td>-43.59%</td>
</tr>
<tr>
<td>110%</td>
<td>14</td>
<td>0.9</td>
<td>-43.59%</td>
</tr>
</tbody>
</table>

Cos Phi (U)

Q (U)

capacitive
inductive
SMA Inverters Q(V) Characteristic

\[ V_{\text{Ar}} \quad V_{\text{QMax}} \]

- \( Q_{\text{min/max}} \)
- \( V_{\text{ArGradNom}} \)
- \( V_{\text{VolNomP1}} \), \( V_{\text{VolNomP2}} \)
- \( V_{\text{VolWidNom}} \)
- \( \pm 0\ldots50\% \) of \( P_{\text{max}} \)
- \( 0\ldots20\% \) of \( V_{\text{Grid-Nom}} \)
- Voltage Deadband 1 & 2, 0.8pu to 1.20pu
- Reactive Power Gradient (0 to 10\%P_{\text{max}}/V_{\text{inv-nom}})
The inverter can be operated at any point inside the PQ-diagram. The red lines represent PF limits of 0.9 leading to 0.9 lagging. The reactive limits are expanded to 0.44pu when QREG=1.
Objective: Stay connected during HV grid disturbances in a manner similar to FERC Order 661-A. Why? To avoid simultaneous shutdown of generation sources.

Required performance:
- Voltage dips to “0” at utility interconnection point (HV side of the transformer)
- Inverter must stay connected during a grid failure for 150 ms (7.5 cycles for 50Hz systems)
- If within 150 ms voltage is back above Limit 1: stable operation
- If after 150 ms voltage stays below Limit 2 (30% of V_{nom}): May disconnect from the grid
- If voltage between Limit 1 and Limit 2, then recovery behaviour to be defined by utility interconnected to.

SMA Inverters are Designed to Support LVRT Requirements Worldwide

Source: Erzeugungsanlagen am Mittelspannungsnetz. BDEW, Release June 2008
LVRT Or Fault Ride Through – Worldwide

Worst Case?

Voltage[pu]

0.15 0.75 1.0

0 250ms 625ms

may disconnect

[sec]
LVRT for North America: Supported

No Tripping

Prefault Period | Voltage Recovery Period

Fault Clearing Period

Courtesy ERCOT Operating Guide
Reactive Current Supply During Fault Ride-Through

- **Targets**: Faster recovery of the grid after grid failures
- Reactive current supply in the event of dramatic voltage drops
- Avoid simultaneous shutdown of significant renewable sources
- No significant influence on PV inverter design.
Grid Support: Automatic Voltage Regulation

Automatic Voltage Regulator

Automatic Reactive Power Regulator
Grid Stability: Dynamic Models

SMA Inverter Dynamic Stability Models for PSSE Versions, 29, 30, 31, 32 & PSLF Versions 16, 17
RMS Modeling of SMA Sunny Central CP

**Modeling approach**

1st step: Derivation of an RMS model from instantaneous value models in Matlab/Simulink
   » Verification against accurate models

2nd step: Manual translation of the Simulink model to DIgSILENT PowerFactory (Version 14.0.519.1)
   » Validation against measured data

   DIgSILENT Model Validation by 3rd party
   Germanischer Lloyd

3rd step: Manual translation of the DIgSILENT model to PSS/E FLECS code (Version 32.3)
   » Verification against PowerFactory simulations using representative test cases
   » Test in representative networks
The Time May Have Come!

“We are like tenant farmers chopping down the fence around our house for fuel when we should be using Nature’s inexhaustible sources of energy – sun, wind and tide. I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that.”

Thomas A. Edison, 1931.
Since 2003, the White House in Washington DC has produced solar energy. A PV system as well as a solar-thermal station is installed on the roof of the main administration building. The grid-connected PV system has an output of 10 kilowatt peak (kWp) and provides some parts of the Presidential residence with solar energy.

With three Sunny Boy 2500U devices, SMA delivered the best fitting inverters for this system. Equipped with the OptiTrac MPP control, the PV generator will always be operated at the optimal power point, even under fluctuating weather conditions.