Application of SAM to the K·A·CARE Distributed Generation Portal

Presentation to the SAM Developer Conference

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Saudi Arabia is Introducing a Net Billing Program for Distributed PV

- KSA plans to implement net billing to control future price paid for PV electricity as rates change
- Net billing converts exported electricity to a financial credit immediately at the time of export
- If the export credit is not the same as the consumption tariff, the cost-benefit of the PV system must account for the balance between consumption and generation throughout the day
Implementation of the Distributed PV Program is an Intergovernmental Effort

• Under leadership of the Ministry of Energy, Industry, and Minerals (MEIM)

• Key roles by Electricity and Co-Generation Regulatory Authority (ECRA), Saudi Electricity Company (SEC), and King Abdullah City for Atomic and Renewable Energy (K·A·CARE)

• K·A·CARE’s roles:
  – Provide consumer-facing information resources, including an independent assessment of benefit to consumers
  – Provide certified training courses for PV designers and installers
  – Provide assessment and advice on PV-related standards for equipment and processes
Shamsi Portal

• “Shamsi” means “My Sun” in Arabic
• The Shamsi portal will support consumers, designers, installers, and permit applicants in the process of designing and installing distributed PV systems

Educative Content
Public awareness and education about solar energy and its benefits

Performance Assessment
Assesses the energy to be produced for a selected location and system configuration

Financial Feasibility
Analyzes financial aspects of solar system based on energy produced and predicts savings and return on investment.

Contractors and Quotations
Communication channel to request Quotations from registered contractors
Solar Calculator

The solar calculator is directly using the open-source System Advisor Model (SAM) developed and maintained by the US National Renewable Energy Laboratory (NREL).

Detailed User inputs:
- Location
- System type
- Module quality
- Elevation tilt
- Azimuth orientation
- DC-AC ratio
- System losses
- Ground coverage ratio

Direct user input

Estimate from area

System size

Location (lat,lon)

Solar resource csv file

SAM ssc.dll

Optional with defaults

Display output:
- Table of monthly PV generation
- Hourly PV energy generation ac[0..8759]

Area input

Input Area

Estimate from area

SAM ssc.dll

Optional with defaults

Display output:
- Table of monthly PV generation
- Hourly PV energy generation ac[0..8759]
K·A·CARE National Renewable Energy data center (NREDC)

Solar monitoring network

- High accuracy ground measurement network
- Based on the US National Solar Radiation Database (NSRDB) operated by NREL
- Operational since 2013
Solar Irradiance Estimation with Neural Network Algorithm (SIENNA) — Satellite model

SIENNA uses images from the EU Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI)

- The model has a total of 10 inputs (6 thermal channels, 4 solar geometry variables)
- Data (satellite images) are subdivided into cloudy and cloud-free regions
- Four sets of ANNs:
  - DNI cloud-free
  - DNI cloudy
  - DHI cloud-free
  - DHI cloudy
- GHI is calculated by $GHI = DHI + DNI \times \cos(\theta_{zenith})$
- In order to further reduce prediction errors, there are 30 ANNs for each of the 4 sets above
- The final prediction is the median value of the 30 ANN outputs
SIENNA Typical Meteorological Year (TMY) Dataset

- SIENNA has been used to produce the following data products for KSA stakeholders:
  - Long-term time series (April 2004 to December 2014)
  - 50th percentile TMY
  - 90th percentile TMY
- Both 50th and 90th percentile TMY support technical and financial analyses
- SIENNA satellite model (source for all TMY and time series) is calibrated using the high-accuracy ground data collected by the K·A·CARE NREDC Atlas project.
- The TMY files generated in this project include files for
  - 46 Atlas sites
  - The 148 largest Saudi cities and towns
  - 17,400 locations providing a 0.1° × 0.1° grid over the land mass of Saudi Arabia
- Providing a TMY file within 8 km of any location in the country
- Improved month selection algorithm provides very close match to target irradiance

<table>
<thead>
<tr>
<th>Mean error</th>
<th>σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual 50th percentile (P50) GHR</td>
<td>0.036%</td>
</tr>
<tr>
<td>Annual 50th percentile (P50) DNR</td>
<td>-0.053%</td>
</tr>
<tr>
<td>Annual 90th percentile (P90) GHR</td>
<td>0.467%</td>
</tr>
<tr>
<td>Annual 90th percentile (P90) DNR</td>
<td>0.130%</td>
</tr>
</tbody>
</table>
Advantages of Using SAM for Solar Calculations

• Calculations are complete and rigorous, accounting for
  – Orientation
  – Tracking
  – Sun position
  – Sky conditions
  – Module temperature derating
  – Shading
  – Inverter efficiency and clipping

• The model has been validated with hundreds of real-life systems.

• The model is actively supported and maintained by NREL, and if improvements are made they can easily be incorporated in our own implementation.

• The model is well-known to all solar professionals and thus does not have to be independently documented and defended by K·A·CARE.
Financial Calculator

**User hourly Load Profile**

$L_{h,u}$

**First year savings**
- Net hourly and monthly consumption
- Net hourly and monthly exports
- Monthly electric bill without solar
- Net monthly bill for consumption with solar
- Monthly export credit
- Monthly and annual savings

**Savings over the life of the system**
- With degradation
  - Net hourly and monthly consumption
  - Net hourly and monthly exports
- With tariff escalation
  - Monthly electric bill without solar
  - Net monthly bill for consumption with solar
  - Monthly export credit
  - Monthly and annual savings

**Simple payback and return on investment (ROI)**

**System life**
- PV system cost per Watt
- Financing parameters

**Service region map**
- Location (lat,lon)
- Hourly PV energy generation ac[0..8759]

**Normalized load profiles**
- User average monthly bill (SAR)
- User 12-month billing history (SAR)

**Tariff Tables**
- Consumer type
- User average monthly load (kWh)
- User 12-month load history (kWh)
- Tariff escalation rate

**Display output:**
- Graph of monthly PV generation, consumption with and without PV, net exports
- Graph of monthly bill without solar, consumption bill with solar, export credit, and net electric bill
- Simple payback and ROI
- Downloadable PDF report
Service region map

• The user selects his location on a map input interface
• The selected location is used to automatically determine:
  – Standard solar resource/weather
  – Service region (for load profile seection)
• “Standard” load profiles have been created from an aggregation of load profiles for each consumer class and region (using data from smart meters collected country-wide by SEC):
  – Consumer classes:
    • Agricultural
    • Commercial
    • Government
    • Industrial
    • Private Hospitals & Schools
    • Residential
  – Service regions
    • Central, East, South, West
Software Environment – Development and Production

• First implementation was an Excel spreadsheet, coupled with a stand-alone C program to run PVWatts
  – The Excel example was used as a guide for the web developers

• Developers are using the following tools to implement Shamsi:
  – Visual Studio 2017 with C# for all coding including interface to SAM
    • We used the SAM code generator to get the initial code for the SAM interface
  – SharePoint, HTML, CSS, Javascript
  – WebAPI tool in C# (MVC.NET)
  – Angular CLI for user interface for simple binding of objects to back-end fields
  – SQL Server database (but SAM solar resource files are stored as individual files)
  – Customer Relationship Management (CRM)

• The coding to incorporate SAM into the website has proceeded smoothly
Summary and Conclusion

• Saudi Arabia is implementing its first nation-wide distributed PV regulation
• K·A·CARE is supporting this implementation by providing an online portal for consumers and other stakeholders to assess PV performance and financial benefit
• Use of the SAM API has greatly facilitated our work
  – Enabled an accurate calculation based on PV Watts and K·A·CARE-supplied solar resource data
  – Easy implementation of the interface to the website
• Using SAM will lend credibility and confidence to all stakeholders
• Thanks to the SAM development team for their outstanding work and support
Thank you
Solar Calculator Inputs

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value(s)/Type</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Latitude and longitude in degrees</td>
<td>None: the user selects the location interactively from a map</td>
</tr>
<tr>
<td>System type</td>
<td>0=fixed open rack 1=fixed close mount 2= single axis tracking 3= single axis tracking with backtracking 4= dual axis tracking</td>
<td>0</td>
</tr>
<tr>
<td>Module quality</td>
<td>0=standard 1= premium 2= thin film</td>
<td>0</td>
</tr>
<tr>
<td>Elevation tilt</td>
<td>float (degrees)</td>
<td>set to latitude of user location</td>
</tr>
<tr>
<td>Azimuth orientation</td>
<td>float (degrees clockwise from north)</td>
<td>180</td>
</tr>
<tr>
<td>System size</td>
<td>float (kW dc)</td>
<td>4</td>
</tr>
<tr>
<td>DC-to-AC ratio</td>
<td>Float</td>
<td>1.2</td>
</tr>
<tr>
<td>System losses</td>
<td>Float</td>
<td>14.0</td>
</tr>
<tr>
<td>Ground coverage ratio</td>
<td>Float</td>
<td>0.4</td>
</tr>
</tbody>
</table>

- Location and system size are required inputs
- Others are initially concealed, and supplied with defaults
- Balance between simplicity and offering more advanced calculation to informed customers / installers
Financial Calculator Inputs

- Location is passed from the solar calculator
  - Used to lookup service region
- Flexible options for specifying load from consumption history
  - Used with service region to determine hourly load profile
- Other options initially concealed, supplied with defaults

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Value(s)/Type</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Latitude and longitude in degrees</td>
<td>This location is the same one selected for the solar calculator</td>
</tr>
<tr>
<td>Consumer type</td>
<td>One of the following choices:</td>
<td>Residential</td>
</tr>
<tr>
<td></td>
<td>• Residential</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Government</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Health &amp; Education</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Industrial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Agricultural</td>
<td></td>
</tr>
<tr>
<td>Electricity consumption</td>
<td>4 optional input sets:</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>• Average monthly consumption</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Monthly consumption for 12 months</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(12 inputs for January .. December)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Average monthly electricity bill</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Monthly electricity bill for 12 months</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(12 inputs for January .. December)</td>
<td></td>
</tr>
<tr>
<td>Installed cost per Watt of PV system</td>
<td>SAR/W</td>
<td>4.5 (min 1.0, max 20.0)</td>
</tr>
<tr>
<td>Fraction financed</td>
<td>Percentage of total system cost</td>
<td>0% (min 0%, max 100%)</td>
</tr>
<tr>
<td>Monthly Payment</td>
<td>Financing details (not shown unless fraction financed &gt; 0%)</td>
<td>0.0966×System cost (10y @ 3%)</td>
</tr>
<tr>
<td>Number of payments</td>
<td>120 (min 12, max 300)</td>
<td></td>
</tr>
<tr>
<td>System life</td>
<td>Years (int)</td>
<td>25 (min 10, max 50)</td>
</tr>
<tr>
<td>Tariff escalation</td>
<td>float</td>
<td>3% per year (min 0%, max 5%)</td>
</tr>
<tr>
<td>PV degradation rate</td>
<td>Float</td>
<td>0.75% per year (min 0.5%, max 1.5%)</td>
</tr>
</tbody>
</table>