How some off-grid renewable energy mini grids have adapted to grid arrival: Lessons from Cambodia, Sri Lanka, and Indonesia

South South North
Cape Town, South Africa

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Mini grid options after arrival of the main grid

+ Small Power Distributor (SPD)
+ Small Power Producer (SPP)
+ Both SPD and SPP
+ Separate systems in the same village
+ Buyout by utility
+ Assets abandoned
Arrival of the main grid

Key: 

= power from utility

= power from SPP

= meter
Arrival of the main grid
Small Power Distributor (SPD)

Key:
- = power from utility
- = power from SPP
M = meter

Diagram:
- Customers
- National Grid
- Large Plants
- Mini-Grid
- Small Power Producer

The diagram illustrates the flow of power from different sources to customers. It shows the interconnection between the national grid, large plants, mini-grid, and small power producers, along with the use of meters to measure the power.

[Diagram description: The diagram shows a network of power distribution from the national grid to customers through large plants and a mini-grid. The key explains the symbols used: arrows for utility power, solid lines for power from small power producers, and M for meters. The diagram visually represents the flow of power through these interconnected systems.]
Cambodia: from isolated mini-grid to SPD

>250 mini-grids became SPDs

Electricity Authority of Cambodia (EAC) put in place a comprehensive program:

- Long-term distribution licenses required...
  To acquire one a mini-grid must:
  - Invest in utility-quality distribution network
  - Extend network thru service territory
- Grants and loans
- Retail tariffs standardized and cross-subsidized for distribution franchisees.

Key: \( \text{utility} \rightarrow \text{SPP} \rightarrow \text{meter} \)
Cambodia: from isolated mini-grid to SPD
+ **Nepal**
  - >200 community owned SPDs
  - Communities provide 20% of capital cost, government 80%.

+ **Bangladesh**
  - 80 rural electric cooperatives
  - A national level cooperative Rural Electricity Board (REB) invests in transformers and transmission/distribution lines.

+ **Burkina Faso**
  - >75 cooperative concessionaire SPDs
  - Transmission (100% grant) and distribution (60% grant + government loans)
SPDs Technical (easy!)

MV – e.g. 33 kV

Fused disconnect
Transformer

House connections
SPD Tariffs

Key:

- = power from utility
- = power from SPP
M = meter
SPD tariffs in Cambodia

- Wholesale and calculated cost recovery tariff vary from project to project.
SPD tariffs in Cambodia

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- Retail tariffs fixed at $0.12 or $0.20 per kWh depending on customer type.
SPD tariffs in Cambodia

- Wholesale and calculated cost recovery tariff vary from project to project.
- Retail tariffs fixed at $0.12 or $0.20 per kWh depending on customer type.
- Operating subsidy paid for by Rural Electrification Fund.
SPD tariffs in Cambodia

- Wholesale: 0.8 USD per kWh
- Ag or Retail consuming <10 kWh per month: 0.2 USD per kWh
- Retail consuming >10 kWh per month: 0.6 USD per kWh
- Diesel mini grids: 1.2 USD per kWh
Small Power Producer (SPP)

Customers

Large Plants

National Grid

Small Power Producer

Mini-Grid

Key: $\text{utility} = \text{power from utility}$, $\text{SPP} = \text{power from SPP}$, $M = \text{meter}$
Sri Lanka: from isolated mini-grid to SPP (sometimes)

- >250 isolated community-owned hydropower built with financial support from GoSL, GEF and World Bank

- With arrival of national grid >100 mini-grids abandoned

- Three projects: 12 to 45 kW converted to SPPs
  - Five more in pipeline
  - No longer provide retail sales to village

Key: \[\text{= power from utility \quad = power from SPP \quad M = meter}\]
Sri Lanka: from isolated mini-grid to SPP (sometimes)
To interconnect as an SPP, the generator must:

- Synchronize with the national grid
- Reliably disconnect in the event of a power disturbance (unless disconnecting will make the disturbance worse)
- Requirements depend on:
  - Generation type (inverter, induction, synchronous)
  - Interconnection voltage (LV, MV)
SPP - inverter interconnection

+ Inverter must meet grid-interconnection standards – e.g. UL 1741 or UL 1741 SA
  
  • Under/over voltage (27/59)
  • Under/over frequency (81)
  • Phase and ground overcurrent (50/51 and 50/51N)
  • Anti-islanding protection
SPP - rotating generation (induction or synchronous)

Generator interconnects through protection relay

- Under/over voltage (27/59)
- Under/over frequency (81)
- Phase and ground overcurrent (50/51 and 50/51N)
- Zero sequence overvoltage (59N)
- Directional overcurrent
- Instantaneous overvoltage (27R)
- Sync check (25)
SPP - Asynchronous (induction) generator

- Under/over voltage (27/59)
- Under/over frequency (81)
- Phase and ground overcurrent (50/51 and 50/51N)
SPP - Synchronous generator

- Under/over voltage (27/59)
- Under/over frequency (81)
- Phase and ground overcurrent (50/51 and 50/51N)
- Synch check (25)
- Directional overcurrent (67)
- Instantaneous over-voltage (27R)
- Zero sequence overvoltage (59N)
SPP Feed-in tariff

Key: = power from utility = power from SPP = meter

Customers

Large Plants

National Grid

Small Power Producer

Mini-Grid

Feed-in tariff
## SPP Feed-in tariff: utility vs SPP costs?

Two different approaches to determining feed-in tariffs

### Utility’s marginal avoided cost

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the marginal cost per kWh incurred by the utility?</td>
</tr>
<tr>
<td>(That is, if the utility had to purchase more electricity, what would it pay for that next unit?)</td>
</tr>
</tbody>
</table>

### SPP’s generation cost (technology-specific)

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the tariff necessary for a well-run facility to earn a reasonable profit?</td>
</tr>
<tr>
<td>Generally technology-specific:</td>
</tr>
<tr>
<td>Solar PV: $0.0X/kWh</td>
</tr>
<tr>
<td>Hydro: $0.0Y/kWh</td>
</tr>
</tbody>
</table>
Feed-in example from Tanzania: utility avoided cost

### Tariffs for Main Grid Connection under the First Generation SPP Framework

<table>
<thead>
<tr>
<th>Description</th>
<th>2018 Tariff (TZS/kWh)</th>
<th>Approved Tariff effective 1st May 2019 (TZS/kWh)</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standardized Small Power Purchase Tariff</td>
<td>203.11</td>
<td>203.11</td>
<td>0%</td>
</tr>
<tr>
<td>Seasonally adjusted Standardized SPPT Payable in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry season</td>
<td>243.73</td>
<td>243.73</td>
<td>0%</td>
</tr>
<tr>
<td>Wet season</td>
<td>182.80</td>
<td>182.80</td>
<td>0%</td>
</tr>
</tbody>
</table>

Source: EWURA. The Electricity (Standardized Small Power Projects Tariff) Order, 2019
Feed-in example from Tanzania: technology-specific

### Approved Tariffs for SPPs Selling Electricity to the Grid

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Minihydro USc/kWh</th>
<th>Wind USc/kWh</th>
<th>Solar USc/kWh</th>
<th>Biomass USc/kWh</th>
<th>Bagasse USc/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 - 0.5MW</td>
<td>10.65</td>
<td>10.82</td>
<td>10.54</td>
<td>10.15</td>
<td>9.71</td>
</tr>
<tr>
<td>0.51 - 1 MW</td>
<td>9.90</td>
<td>9.95</td>
<td>9.84</td>
<td>9.34</td>
<td>9.09</td>
</tr>
<tr>
<td>1.01 - 5 MW</td>
<td>8.95</td>
<td>9.42</td>
<td>9.24</td>
<td>8.64</td>
<td>8.56</td>
</tr>
<tr>
<td>5.01 - 10 MW</td>
<td>7.83</td>
<td>8.88</td>
<td>8.34</td>
<td>7.60</td>
<td>7.55</td>
</tr>
</tbody>
</table>

Source: EWURA. The Electricity (Standardized Small Power Projects Tariff) Order, 2019
107 countries have feed-in tariffs
Both SPP and SPD

- National grid
- Large plants
- Customers

- Mini-grid
- Small power producer (SPP)
- Customers

= Power from utility
= Power from SPP
M = Meter
Indonesia: SPD + SPP

Of 200 community-owned mini-grids where national grid has arrived...

- 150 abandoned, PLN takes over.
- 9 have become SPPs/SPDs.
  - Sell all or some electricity to national grid
Co-existence

Customers

National Grid

Large Plants

Extension of National Grid

Customers

Mini-Grid

Small Plant
Co-existence: OMC Uttar Pradesh
Buyout

Customers

Large Plants

National Grid

Customers

Small Power Producer (may operate as emergency backup plant)

but with backup electricity provided by old generator

Mini-Grid

Small Power Producer

Key: = power from utility = power from SPP = meter
**Buyout: Compensation in other countries**

**Nigeria:**
- Straight-line depreciation of all mini grid assets **plus** last 12 months of retail electricity sales revenues

**Tanzania:**
- Distribution assets only -- utility’s avoided cost for same length of distribution line devalued at 4% per year

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**Straight line depreciation assuming 4% annual devaluation**

![Graph showing straight line depreciation over 15 years with remaining value indicated.](chart)
Assets abandoned

Customers

National Grid

Large Plants

Extension of National Grid

Small Power Producer

Customers
Assets abandoned
Lessons

+ Viable examples of formerly isolated village mini-grids connecting to main-grid exist...
  - Hydropower able to remain financially viable selling wholesale to utility (Sri Lanka & Indonesia)
  - Mini-grids with utility-grade distribution networks transitioning to small power distributors (Cambodia)

+ ... but are rare
  - Most mini-grids abandoned when utility arrives

+ Cost of interconnection depends on business model
  - e.g. SPP interconnection more costly than SPD
A Guidebook on Grid Interconnection and Islanded Operation of Mini-Grid Power Systems Up to 200 kW

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Thomas Quetchenbach

April 2013

Photo credit: Chris Greacen
Thank you

Chris Greacen

https://palangthai.wordpress.com/docs/