Quality Assurance Framework for Mini-grids

Ian Baring-Gould
Technology Deployment Manager for Wind & Water
National Renewable Energy Laboratory
Golden, Colorado, USA

A Quality Assurance Framework for Mini-Grids

To address the root challenges of providing quality power to remote consumers through financially viable mini-grids, the Global Lighting and Energy Access Partnership (Global LEAP) initiative of the Clean Energy Ministerial and the U.S. Department of Energy teamed with the National Renewable Energy Laboratory (NREL) and Power Africa to develop a Quality Assurance Framework (QAF) for isolated mini-grids. The framework addresses both alternating current (AC) and direct current (DC) mini-grids, and is applicable to renewable, fossil-fuel, and hybrid systems.

Mini-grids Quality Assurance Framework

- **Purpose:** Provide structure and transparency for mini-grids sector, based on successful utility models, while reflecting the broad range of service levels required to meet the needs of various segments of the off-grid consumer base
- **Importance:** Lay the foundation for successful business models in the mini-grids space

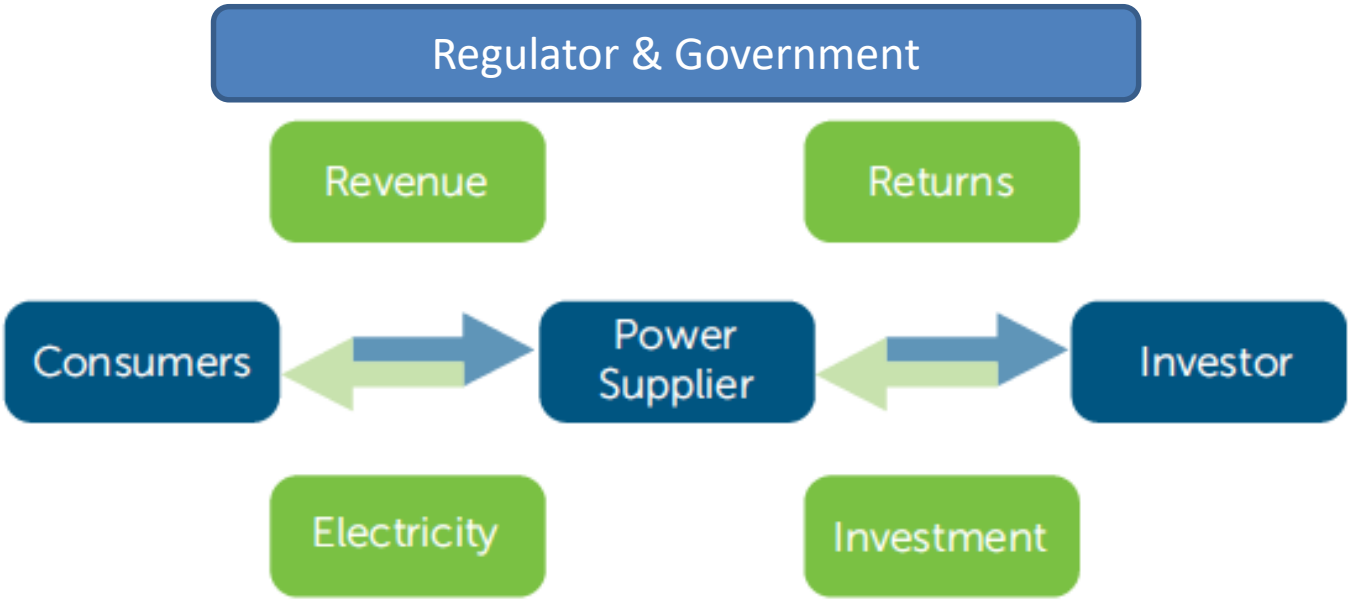
Source: Kari Burman, August 2007

A mini-grid is an aggregation of loads and one or more energy sources operating as a single system providing electric power, and possibly heat, isolated from a main power grid. A modern mini-grid may include renewable and fossil fuel-based generation, energy storage, and load control. Mini-grids are scalable so that additional generation capacity may be added to meet growing loads without compromising the stable operation of the existing mini-grid system.

The Mini-grid Utility Model

Business models for commercially viable mini-grids must address the needs of the four key stakeholder groups:

- **Customer:** Need a guarantee of service that they can afford and are willing to pay for
- **Power Suppliers:** Need to be able to guarantee a rate of return to their investors
- **Investors:** Need to be confident of the risks they are taking
- **Regulators & Government:** Sets the rules, keeps the peace and may contributed funds



Mini-Grids Quality Assurance: Unlocking Investment & Scale-up

- **Provide common technical standard for classifying service from mini-grids** based on well-defined system specifications for different levels of service
- **Strengthen revenue flows by optimizing system design** through more consistent system specifications that are better tailored to different tiers of consumer need and ability to pay
- **Facilitate aggregation, unlocking private investment** through adoption of uniform classification system coupled with accountability framework:
  - Bundle projects with similar attributes
  - Generate robust market information
- **Flexible and adaptable framework:** Which includes AC & DC mini-grids; applicable to renewable, fossil-fuel, and hybrid systems; capture basic to “grid-parity” service

Elements of the Quality Assurance Framework

1. **Define levels of service** tailored to different tiers of consumers, including appropriate thresholds for:
   - Power quality
   - Power availability
   - Power reliability
2. **Define accountability framework**
   - Clear process for verification of power delivery through trusted information to consumers, funders, and/or regulators
   - Provides defined assessment and reporting protocol for operators

The Quality Assurance Framework DOES NOT mandate a standard level of service but provides a more detailed, common way to reference levels of service.

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Peak Available Power (Watts)	None	>1 W	>20 W	>200 W	>2,000 W	>2,000 W
Consumption (kWh/year)	< 3	3 - 66	67 - 321	322 - 1,319	1,319 - 2,121	> 2,123
Duration of Supply (hours per day)	None	> 4 hrs	> 4 hrs	> 8 hrs	> 16 hrs	> 22 hrs
Evening Supply	n/a	> 2 hrs	> 2 hrs	> 2 hrs	4 hrs	4 hrs
Quality	n/a	low	low	Adequate	Adequate	Adequate
Typical Applications (Cumulative)	None	Radio, Task lighting	General Lighting, fans, TV, light office needs	Air cooling, food processing, and task oriented food preparation	Refrigeration, water heating, pumps, expanded food preparation	Air conditioning, space heating and full food preparation

Levels of Service for Isolated Mini-grids

1. **Power Quality** – Is the power provided of a reasonable or defined quality to safely provide the energy needs of the consumers?
   - Voltage and frequency variations, distortion etc.
2. **Power Availability** – Is the power provided in the amount that meets expectations and available with the duration that has been specified?
   - Hours of service, power and energy levels, etc.
3. **Power Reliability** – Is the power provided with enough reliability to meet consumer needs?

Source: Kari Burman, November 2016

Source: Solar Nigeria, 2014

Mental Model – Rural Energy Needs

- A heavy duty pick-up truck is a good mental model of “grid parity” power. It’s great to have but expensive to own and operate.
- Most people in rural communities don’t have the need for grid parity power supply, a moped is more appropriate and much lower cost.

Power Quality Issues

- Voltage Unbalance (AC)
- Transients (AC & DC)
- Short Duration Variations (AC & DC)
- Long Duration Variations (AC & DC)
- Waveform Distortion (AC & DC)
- Voltage Fluctuations/Flicker (AC & DC)
- Frequency Variations (AC)

AC Power Quality Issues

Issue	Base Level of Service	Standard Level of Service	High Level of Service
AC Power Quality Phenomena			
Voltage imbalance	<10%	<5%	<2%
Transients	No protection	Surge protection	Surge protection
Short voltage duration variations	<5/day	<1/day	<1/week
Long voltage duration variations	<10/day	<5/day	<1/day
Frequency variations	48 Hz < f <52 Hz	49 Hz < f <51 Hz	49.5 Hz < f <50.5 Hz

- Voltage phase unbalance
- Transients outside of system insulation design
- Short duration voltage variations due to faults lasting <1min
- Long duration voltage variations due to faults lasting >1min
- Voltage waveform Distortion- Fluctuations/Flicker
- Frequency Variation

What is Power Availability?

- The amount of energy services being provided to specific customers based on need and other factors. Three main criteria :
  1. **Power:** Maximum draw in Amps or Watts
  2. **Energy:** Total energy available (kWh) over a defined time period (month, year)
  3. **Time of day service:** For what hours of the day is power available (hours per day)
- Availability ties together the parameters that define how much energy service is to be provided to a specific customer based on their ability and willingness to pay for that service. Expected to change over the life of the utility/customer relationship
- Consistent with the World Bank Multi-Tier Framework but expands on the details taking a more power system focused approach

Energy Available Per Time Period

- Would typically be tabulated over a period of time (month or year) even if pre-pay meters focused on energy were used
- Minimum and maximum levels of service for different customers could be specified
- Different rates could be applied to different levels of service

Energy Level	Peak Level (kWh/year)
Level 1	>4.38
Level 2	>73
Level 3	>365
Level 4	>1,250
Level 5	>3,000
Level 6	>73000

Power Reliability

Represents how well the power system provides power during times when power should be provided.

Source: Canadian Pacific, flickr 2013

- **Unplanned power outages**
  - System Average Interruption Frequency Index (SAIFI)
  - System Average Interruption Duration Index (SAIDI)
- **Planned power outages**
  - Planned System Average Interruption Frequency Index (P-SAIFI)
  - Planned System Average Interruption Duration Index (P-SAIDI)

Power Reliability - Unplanned Outages

Unplanned Outages:

Level of Service	SAIFI Interruption$_{24}$ Frequency*	SAIDI$_{24}$ Interruption Duration*
Base	<52 per year	<52,560 minutes (876 hours) 90% reliability
Standard	<12 per year	<26,280 minutes (438 hours) 95% reliability
High	<2 per year	<90 minutes (1.5 hours) 99.99% reliability

*SAIDI and SAIFI values provided assume 24 hours per day of expected service. If fewer than 24 hours per day are to be provided, an adjustment of the specific threshold values for SAIFI and SAIDI should be made and a subscript added to reflect the expected hours of service per day.

Planned Outages:

Level of Service	P-SAIFI$_{24}$ Interruption Frequency*	P-SAIDI$_{24}$ Interruption Duration*
Base	No requirement but should be defined	No requirement but should be defined
Standard	No requirement but should be defined	No requirement but should be defined
High	<2 per year	<30 minutes - 100% reliability

*P-SAIDI and P-SAIFI values provided assume 24 hours per day of expected service. If fewer than 24 hours per day are to be provided, an adjustment of the specific threshold values for P-SAIDI and P-SAIFI should be made and a subscript added to reflect the expected hours of service per day.

Accountability Framework

1. **Consumer Accountability** defines, demonstrates, and validates that a specific level of service is being provided to a customer
   - Level of Service verification
   - Service Agreement

Source: NREL PIX #07805

2. **Utility Accountability** allows funding or regulatory organizations to understand if the system is safe and providing contracted service
   - Technical reporting
   - Business reporting
   - Reporting template

Source: Jake Lyell for the Millennium Challenge Corporation

Consumer Accountability Framework

Level of Service Verification

- Ability to record energy consumption
- Ability to record hours of service at service drops
- Ability to check voltage levels at service drops
- Implementation of periodic, random, and documented voltage surveys to ensure proper quality of service

Service Agreement

- Defines applicable power quality standards in place
- Identifies what type of investigation is warranted based on complaints
- Describes how to address power quality impacts caused by the customer vs. those caused by the power system (utility)

Utility Accountability Framework

Provides a defined and secure methodology for utilities to provide relevant information to regulators and project financiers, essentially the information that will allow a good understanding of the utility business

Information about the performance of the utility

- Technical Reporting: Measurements addressing system performance, energy usage, operational issues
- Business Reporting: Payment collection rates, electrification rates, customer characteristics, service calls and safety concerns, etc.

Reporting Template

- Standard document or procedure that provides performance information to the funder/regulator, providing consistency across energy platforms and projects.

Mini-Grid Implementation – Stakeholder Mapping

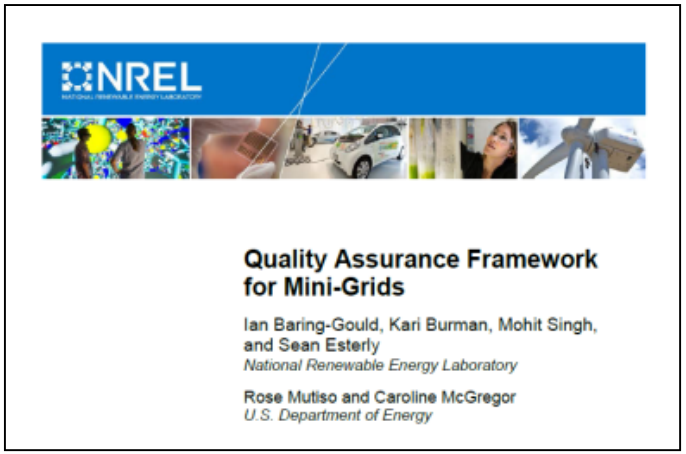
Program Development Step	Regulator	Ministry	Developers	Mini-utility	Investors	Customers
1. Specify project goals	●	●			●	
2. Develop policy and ownership frameworks	●	●				
3. Develop reporting and measurement requirements	●	●	●	●	●	
4. Develop performance, monitoring, and reporting plans/procedures	●	●		●	●	
5. Develop a project or program quality assurance verification process	●	●		●	●	
6. Develop program and project documentation	●	●			●	
7. Implement quality assurance verification process	●	●			●	
8. Implement the electrification/mini-grid deployment project	●	●	●	●	●	●
9. Collect and analyze long-term system operational data	●			●	●	●

The QAF is designed to help governments understand each of these steps in the development of minigrid power systems in a uniform, industry consistent way

A Quality Assurance Framework for Mini-Grids

All documents available at:
https://cleanenergysolutions.org/qaf

- Technical Report
- Implementation Guide
- Fact sheet and presentation



Technical documents being added: Commissioning guide, load forecasting tools, community surveys etc..

Supported by:

- Global Lighting and Energy Access Partnership (Global LEAP) initiative of the Clean Energy Ministerial and the
- U.S. Department of Energy teamed with the
- National Renewable Energy Laboratory
- Power Africa

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Questions and Contact Information

Ian Baring-Gould
303-384-7021
Ian.baring-gould@nrel.gov
https://cleanenergysolutions.org/qaf

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