EarthSpark Distribution System Medium Voltage Discussion – 12.47 kV vs 22.9 kV

Purpose:

This document was compiled by the EarthSpark team as a retrospective on why EarthSpark selected 12.47 kV for the Les Anglais microgrid medium voltage distribution network. This decision was made after deep consultation with several microgrid design experts, including Myk Manon of NRECA who was working with EdH at the time.

EarthSpark wishes to contribute to the current discussions among Haitian government policy makers about technical standards for community microgrids in Haiti.

Summary:

Microgrids in Haiti are currently built to different medium voltage standards. When overall demand is modest and especially when solar and battery inverters play a significant role in supplying power, it is important to choose the voltages carefully.

EdH's medium voltage standards for rural areas are 12.47 kV and 22.9 kV. The 12.47 kV standard has the following advantages over the 22.9 kV standard for community microgrids:

- Lower cost to install
- Lower cost to operate
- Easier and more reliable grid operations
- Better power quality for end users
- Standardized equipment + access to replacement parts (12.47 is the standard for EdH distribution in PAP)

While there may be tendency to assume that 'bigger is better' for economic development, note that most rural utilities in the United States started with 4.16 kV and some have only recently converted to a higher voltage. Also note that if rural electrification is accompanied by a provider of deeply-efficient end-uses, and/or smart meters with demand management programs, relatively low aggregated instantaneous consumption levels can unlock significant energy services and economic development.

Context:

In collaboration with the Ministry of Public Works, Transportation, and Communications (MTPTC), EdH, and the municipality of Les Anglais, EarthSpark International launched a prototype microgrid in Les Anglais in 2012 and expanded that grid to a 'town-sized solar-powered smart grid' in 2015. That grid was providing 24h electricity service to 451 connections (about 2000 people) until it was struck by Hurricane Matthew in 2016. EarthSpark has worked with local partners to fully repair the Les Anglais distribution system (at 12.47 kV) and has so far relaunched service for 206 connections. Full reconnection for all pre-storm customers who are ready for reconnection should be completed in June.

Meanwhile, the microgrids in Tiburon and Coteaux (CEAC) were built using the 22.9 kV standard. Responding to Hurricane Matthew, CEAC has repaired its lines, and the Tiburon distribution system repairs will soon be underway. Given that the reconstruction of the Tiburon microgrid distribution system is imminent, it is important to consider the relative merits of the different voltages to rebuild the system.

Medium-Voltage Discussion and Rationale:

This document was compiled by the EarthSpark team as a retrospective on why EarthSpark selected 12.47 kV for the medium voltage backbone of the distribution system. The EarthSpark microgrid in Les Anglais is not alone in being a regional grid in Haiti with 12.47 kilovolt (kV) medium voltage distribution system. Électricité d'Haïti (EDH) standards for medium voltage lines are: 12. 47 kV for mini-grids and 22.9 kV for rural areas. EDH standards in Port-au-Prince are 12.47 kV.

Two primary factors led to the selection of 12.47 kV over 22.9 kV for Les Anglais. The first was technical: a 22.9 kV system is likely to have power quality problems when serving community-scale microgrids. The higher the voltage on a conductor, the greater the potential for inductive losses. If resistive loads are low due to low consumption, the potential arises for poor power quality in the system in the form of high reactive loads relative to resistive loads (aka low power factor). This can occur after initial startup when there are fewer customer connections to the system and potentially ongoing at non-peak periods of a typical 24-hour period. For example, from midnight to 4am consumption is typically low with possibly induction motors from freezers making up the bulk of the customer load. A poor power quality system can mean unnecessary inefficiencies in the distribution network with a relatively significant percentage of generation being used to meet wasteful reactive losses.

Other potential effects could result at the generation facility, particularly at the inverters. For instance, an inverter might trip when the power factor drops below a certain value to protect the internal circuitry from irreparable damage. In the Les Anglais PV and master inverters, for example, AC load port specifications state an allowable power factor of 1.00 to 0.85 (lagging). Without power factor correcting capabilities, such as additional capacitors or new inverter power factor correcting functionality, the system reliability could be compromised. Keeping the system at 12.47 kV instead of 22.9 kV helps mitigate this concern resulting in a more reliable system.

The second element informing the decision was cost: building a 12.47 kV system costs less to build and operate than a 22.9 kV system does.

For consideration of how the Tiburon distribution system should be rebuilt and for assessment of 'futureproofing the Les Anglais grid', EarthSpark has commissioned a study on options for future interconnection. A preference for the ability to connect to the national grid immediately is understandable but affiliated costs and effects on the system must be considered. The main question is whether the initial integrity, efficiency, and operating costs should be sacrificed for the sole purpose of future interconnection that may or may not occur anytime soon.

Appropriately rated transformers (both step up and step down) will be necessary to accommodate 22.9 kV but other costs must be considered as well. All medium voltage insulators should be evaluated to determine whether their ratings accommodate a transition to an elevated voltage and replaced if not.

Although the Les Anglais generation system was designed to accommodate interconnection with the national grid in regard to the transition between "grid leading" and "grid following" modes and automated synchronization, a means of physically disconnecting and reconnecting to the point of medium voltage (or at low voltage if additional transformers are installed) will need to be accounted for in cost considerations and interconnection planning.

EarthSpark has identified a number of methods in which future interconnection could be considered:

Table 1: Potential Interconnection Approaches

#	Approach	Description	Pros	Cons
1	Maintain 12.47 kV after national grid interconnection.	At point of interconnection, install step down transformers to transition from national grid 22.9kV to 12.47 kV. All installed equipment by Enèji Pwòp will remain in place.	Cost occurs only at the time of interconnection. Possibly lowest cost scenario. Least time intensive scenario. Avoids potential power quality concerns.	May require custom transformer(s).
2	Transition to 22.9 kV after national grid interconnection.	Once national grid is ready to connect, convert LA distribution system over to 22.9 kV.	Cost occurs only at the time of interconnection. Avoids potential power quality concerns. Simpler for future expansion by national grid, once connected.	Will require a line team to replace any insulators, transformers, etc. not rated for 22.9 kV.
3	Build community microgrid MV at 22.9 kV prior to grid interconnection.	Build / repair community microgrid MV at 22.9 kV in all cases.	Meeting new national requirements, if applicable.	Potential power quality/reliability concerns. High up-front costs with no guarantee of future benefit. High operational costs associated with inefficient grid operations.

Approach #1 seems to be the best option for community-scale microgrids in Haiti. Option #2 seems the second-best option. In both cases, community microgrids have the opportunity to be constructed cost-effectively and function efficiently and for regulators and other stakeholders to gather more data as they assess possible paths to interconnecting microgrids throughout Haiti. As it is unlikely that interconnection will take place between the national grid and the remote community microgrids within the next few years, it seems logical to build microgrid infrastructure in the most efficient method possible with the highest reliability and cost-effectiveness for the immediate future.