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MICROGRID IMPLEMENTATION ON TRIBAL LANDS

Chelsea Chee
University of New Mexico
Sandia National Laboratories[1]

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Anthony Martino, Manager
Sandra Begay-Campbell, Mentor
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ABSTRACT

The United States electrical power grid is over 130 years old and is currently facing multiple challenges, such as: age, grid expansion, inclusion of variable energy resources, and brown or blackouts. In addition, U.S. Tribes face some of the following energy infrastructure challenges:

- Some tribal members do not have access to electricity because of their rural locations, costly grid expansion, and right-of-way permitting issues.
- Additionally, ~5% of the national renewable energy resources are available on tribal homelands but connecting to transmission lines can be costly.
- Microgrids could be one solution for tribes to increase energy access to their communities. Microgrids could be cost comparable to grid expansion and upgrades; integrate local variable energy resources (which some tribes have); and conserve water use (depending on the energy resources used).

As examples of tribal economic development projects, the Ramona Band of Cahuilla Indians in California have implemented a microgrid for their eco-tourism facility and the Hualapai Tribe in Arizona is planning to implement a microgrid for their Grand Canyon West facilities.

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INTRODUCTION

The subject of this paper, microgrids, was formulated from a combination of the Department of Energy's (DOE) Tribal Energy Program (TEP) field visits and the Sandia National Laboratories' (Sandia) Energy Surety Incubator (ESI) program. DOE's Tribal Energy Program seeks to provide financial and technical assistance for energy reduction and renewable energy development on tribal lands. Many tribal nations have been assisted in various different ways by this program. Two of whom, the Ramona Band of Cahuilla Indians and the Hualapai Tribe, have financial and technical received assistance in renewable energy development; and upon further inquiry via field visits both are interested in microgrid applications to support their economic development endeavors.

Microgrids are topics of discussion for the ESI program around energy surety. For Sandia (2013), energy surety is guided by five principles when working with critical power needs to ensure energy. The Energy Surety principles include safety, security, reliability, sustainability, and cost effectiveness. The safety principle is concerned with the reduction of current and non-creation of new safety hazards. Security is ensuring the resiliency to all threats, especially grid security "…due to the threat of cyber attack" and "intentional sabotage" (Jensen, Baca, Schenkman, and Brainard, 2013, p. 20). Reliability refers to the "ability to provide sufficient power, especially during contingencies" (Jensen et al., 2013, p. 20). "Sustainability is the ability to sustain the power system for an indefinite period of time, but doing so in a manner that does not compromise future demands on the system" (Jensen et al., 2013, p. 20). Cost effectiveness looks to reduce cost of energy systems in a microgrid. Sandia's Energy Surety Microgrid work also follows these principles and worked with DOE's Office of Indian Energy to recommend a future microgrid system for one Alaskan Village. Microgrids are being researched and implemented due to the multiple challenges the existing power electrical grid faces.

THE POWER ELECTRICAL GRID

The 131-year-old United States power electrical grid is a power system comprised of four components: generator, transmission, distribution, and load. There are multiple sources of energy generation, transmission and distribution are made at different scales, and the U.S. has numerous energy loads. Energy is generated through the conversion of coal, natural gas, nuclear, hydropower, biomass, geothermal, solar, wind, petroleum, and other gases (U.S. Energy Information Administration, 2013). Energy is then transported and distributed through power lines and substations at different voltages. Power is transported long distances at 765kV, 500 kV, 345 kV, 230 kV, 138 kV. Transmission is done at higher voltages because it is more efficient and reduces energy loss. It is then distributed to users at 115 kV, 69 kV, and 35-4 KV. Voltage is changed between power lines via substations (MIT, 2011).

Currently, the grid expands about 170,000 miles of high voltage transmission lines and about 6 million miles of lower voltage distribution lines to "serve about 125 million residential customers, 17.6 million commercial customers, and 775,000 industrial customers" (MIT, 2011, p. 5). Reliability and reasonable cost are two of the grid's biggest goals because customers demand it. Thereby, stable and dispatchable power is sourced from coal, natural gas, nuclear, and hydropower because they are predictable. There are several issues that are challenging reliability and cost: aging grid infrastructure, line expansion, and inclusion of variable energy resources.

The American Society of Civil Engineering (2013) identified permitting for line expansion and limited maintenance on the aging infrastructure as issues with the grid, especially with increases in population. Expanding and maintaining the grid will be costly. In addition, reliability will be challenged when variable and unpredictable energy resources (wind and solar) are included into the existing grid. It will also be costly to create more flexibility within the grid to accommodate for the variability and to expand transmission facilities to high resource wind along the "wind belt" from Texas to the Dakotas and solar areas in the Southwest (MIT, 2011). Energy storage systems can help to "smooth out" variability (S. Atcitty, personal communication, June, 27, 2013), although they too can be costly.

Additionally, water is required from all energy generation and is a concern with a limited water supply. The figures below depict water withdrawal by sector and water use for cooling in different electrical generations.

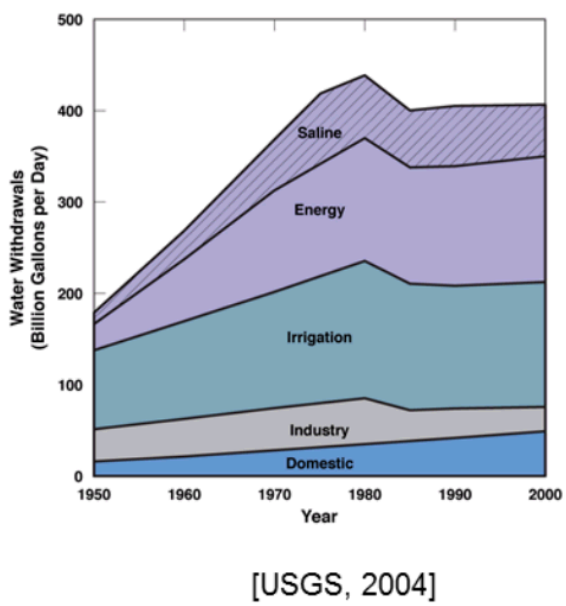

Figure 1: Water Withdrawals by Sector. *Source: Laird (2013)*

Plant-type	Cooling Process	Water Use Intensity (gal/MWh$_e$)		
		Steam Condensing[a]		Other Uses[b]
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine[c]	Open-loop	20,000–50,000	~200-300	~30-90[d,i]
	Closed-loop	300–600	300–480	
	Dry	0	0	
Nuclear steam turbine[c]	Open-loop	25,000–60,000	~400	~30[d]
	Closed-loop	500–1,100	400–720	
	Dry	0	0	
Natural Gas Combined-Cycle[c]	Open-loop	7,500–20,000	100	10[c]
	Closed-loop	~230	~180	
	Dry	0	0	
Coal Integrated Gasification Combined-Cycle[c]	Closed-loop	200	170	150[e,c]
	Dry cooling	0	0	150[e,c]
Geothermal Steam[f]	Closed-loop	2000	1350	NA
Concentrating Solar[g,h]	Closed-loop	750	740	10
	Dry cooling	10	0	10
Wind and Solar Photovoltaics[i]	N/A	0	0	1-2
Carbon sequestration for fossil energy generation				
Fossil or biomass[k]	All	~30% increase in water withdrawal and consumption		

Figure 2: Electric Power Generation Water Use for Various Cooling Options. Source: Laird (2013)

The energy sector withdraws a large amount of water overall; most of which is used for cooling during electric power generation. As Figure 2 indicates, water is withdrawn and consumed at different amounts. It also shows that fossil fuel based generation requires more water versus wind and solar generation.

Extending and maintaining the existing grid while including variable energy resources and being cognizant of water withdrawal and consumption are only some concerns of the future of the United States power electrical grid. Additionally, it is expensive to extend the grid into some areas of the United States. Tribal nations are examples of these circumstances – the electrical grid doesn't extend to all parts of tribal nations, leaving some without electricity, whilst renewable energy generation potential is high. Microgrids can be implemented by tribes to integrate variable energy resources found on their lands and distribute energy locally to areas on and off the grid.

MICROGRID

Friedman and Stevens (2005) define a microgrid as "the operation of distributed generators serving separate loads via a non-utility electrical distribution systems in a coordinated arrangement offering higher reliability to a multiple facility (or multiple load center) site" (p. 7) and present three different classes and modes of microgrids. Classes are dependent on the combination of eight characteristics:

- "Multiple generators severing loads in multiple buildings" (p. 8)
- Existence of a non-utility owned distribution grid, also known as local electric power system (EPS)
- Interconnection to a utility owned distribution grid
- " '[E]vent detection and response' control allowing the microgrid to detect an event or outage on the Area EPS and then to disconnect from the grid and operate as an intentional island" (p.7).
- Centralized generation systems
- Decentralized generation systems
- "A master control system [that] operates the generators as needed to both meet loads and provide voltage and frequency support to the Local EPS" (p.8)
- A "peer-to-peer" control system that allows "local control at each generator's location" (p.8).

The table below depicts three Classes of microgrids based on their characteristics:

Microgrid Characteristic	Simple (Class I)	Master Control (Class II)	Peer-to-Peer Control (Class III)
Multiple generators serving loads in multiple buildings	✓	✓	✓
Served by Local EPS	✓	✓	✓
Interconnected with Area EPS	✓	✓	✓
Event detection and response control	✓	✓	✓
Generators located in central power plant	✓		
Generators distributed among buildings (separate buses)		✓	✓
Master microgrid control	✓	✓	
Peer-to-peer microgrid control			✓

Table 1: Microgrid Characteristics   Source: Friedman and Stevens (2005)

The three modes of microgrids are based on the type of generation (distributed generation or Area EPS) that is supplying the baseload, supplemental, and backup powers, as Table 2 below shows.

Modes	Baseload	Supplemental	Backup
Mode I – Partial Baseload	DG	Area EPS	Area EPS
Mode II – Full Baseload	DG	DG	Area EPS
Mode III – Backup/Peaking	Area EPS	Area EPS	DG

Table 2: Microgrid Operating Modes   Source: Friedman and Stevens (2005)

Friedman and Stevens provide a good introduction into microgrid systems but do not include off-grid systems as microgrids. As such, over time the definition of microgrid has changed to include off-grid systems.

Glenwright (2012) states that the Department of Energy defines a microgrid as "[a] group of interconnected loads and distributed energy resources (DER) with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid [and can] connect and disconnect from the grid to enable it to operate in both grid-connected or island mode". Distributed energy resources (DER) "…are small, modular, decentralized, grid-connected or off-grid energy systems located in or near the place where energy is used" (U.S. DOE, 2012), such as: reciprocating engines, combustion turbines, microturbines, fuel cells, photovoltaic systems, concentrating solar systems, wind energy systems, small modular biopower, and energy storage systems. As discussed before, microgrids are found at different scales, large and small, and are dependent on their location and load. Different combinations of DERs can compose a microgrid, which is depended on its "…application, cost, environmental considerations, and systems size" (U.S. DOE, 2012).

Microgrids have several benefits, some of which includes: the inclusion of medium and low voltage distributed energy generations, "increased energy efficiency through [Combined Heat Power]" (Hatziargyriou, Asano, Iravani, and Marnay, 2007. p. 79), carbon emissions reduction, improved power quality and reliability, reduced line losses, and grid expansion deferral (Hatziargyriou et al., 2007). Energy efficiency is increased and carbon emissions are reduced by "locally utilize[ing] waste heat from conversion of primary fuel to electricity" and reducing energy loss through voltage changes (Hatziargyriou et al., 2007, p. 79). Power quality and reliability are improved by the proximity of the energy source (Hatziargyriou et al., 2007). Another benefit is a reduction in water use when energy generation is localized.

Microgrids are viable options for tribal nations to create energy access for their tribes.

About 5% of the national renewable energy resources are available on tribal homelands but linking to transmission lines can be costly (DOE Office of Indian Energy, N.A.); therefore, tribes could operate microgrids based in the renewable energy sources they have available. Two tribal nations are in the midst of microgrid implementation on their homelands for economic development.

RAMONA BAND – ECOTOURISM

The Ramona Band of Cahuilla Indian's rural land locked reservation limited utility options for their ecotourism resort. Ramona is located on 560 acres at the base of the Thomas Mountain in Anza, CA (Ramona, 2008). The Eco-Resort is part of Ramona's economic development plan and is set to have 40 lodging units, a waste disposal system, electric vehicles, a pool, a conference center, offices, a gift shop, reservation offices, a restaurant, and a cultural center (Dodson, 2007), see Figure 4 below. To date, it has five lodging units.

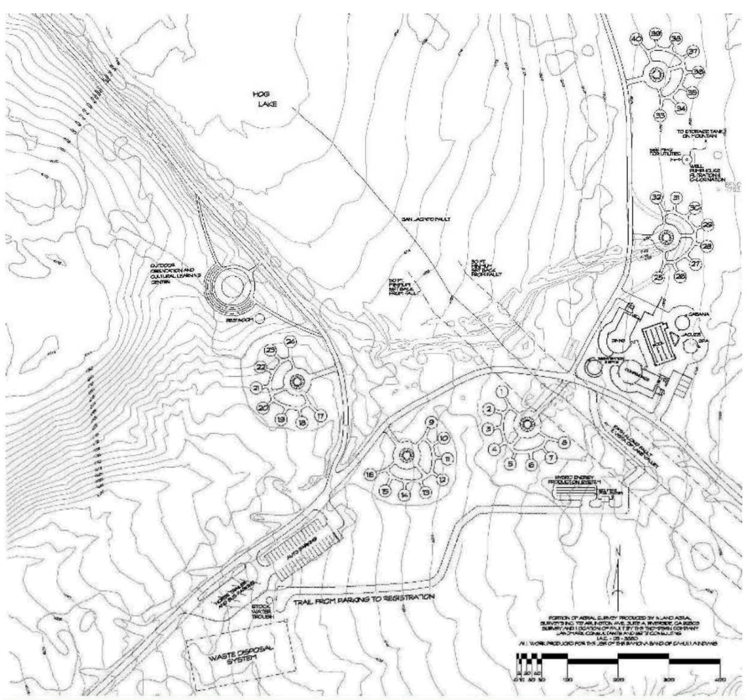

Figure 4: Eco-Resort Master Plan *Source: Schmitt & Davidson (2013)*

The Eco-Resort is powered by two PV arrays producing 10500 W, 48 Absolyte IIP individual batteries, and a 20 kW propane generator are housed in a 12' x 16' power station building. The power station building is equipped with a 15 kVA continuous inverter with a 175 A disconnect. The power is also distributed via underground lines. As the facility expands, it is projected that the existing power supply may accommodate the expansion but "…depending on emerging technologies and an increasing project scope, the power supply may be expanded to accommodate newer buildings and infrastructure" (R. Agunwah, personal communication, July 22, 2013).

This off-grid microgrid option was chosen due to cost, bureaucratic complexities, environmental effects, and stakeholder complications. Mr. Agunwah, Environmental Director for Ramona Band, stated that "[a]ll power line route options had to go through [the United States Forest Service] and [Bureau of Land Management] land to be underground, which would create a visible scar 20' wide along a 7 to 9 mile route causing erosion problems and negative view shed impacts. The total cost of this line would approach $115,000 and utility rates would begin at 12.8 cents per kWh plus a surcharge and could increase each year by as much as 10-15%" (personal communication, July 22, 2013). Additionally, approval for grid line extension from all land stakeholders was difficult to garner (S. Begay-Campbell, personal communication, July 23, 2013) so onsite energy generation was chosen.

The Eco-Resort's microgrid was designed with renewable energy technologies in mind, especially solar, because of the "…Tribe's desire to preserve natural resources, generate tribal revenues, offer job opportunities to tribal members, and benefit other tribes by providing information and training in renewable energy technologies and applications" (R. Agunwah, personal communication, July 22, 2013). The system was designed based on the energy load calculated from the Master Plan with technical assistance from Sandia National Laboratories, of which energy efficiency measures were considered (S. Begay-Campbell, personal communication, July 23, 2013).

To date, the five eco-lodge units are powered by a centralized 10,500W photovoltaic array. With definite site and energy load expansion projected in the future, keeping a centralized energy generation and distribution is a question. The Eco-Resort was supported by multiple government agencies – Department of Energy, Housing and Urban Development Community Development Block Grant, Department of Agriculture, Bureau of Reclamation, and U.S. Forest Service.

HUALAPAI TRIBE - GRAND CANYON WEST

Situated in the northwestern part of Arizona, the Hualapai Tribe's land base covers 992,000 acres, which includes ~53 miles of the Grand Canyon. One of Hualapai Tribe's active economic growth practices is their Grand Canyon West (GCW) tourism facility. GCW is made up of three destination points and a Welcome Center, all including: cabins, eating facilities, air terminal, the Skywalk, arts and crafts facilities, restrooms, gift shops, and bus terminals. GCW had 775,000 visitors in 2012 with increased projections for the future. There are also future facility expansions projected (TTG Engineers, NA).

Figure 5: Map of Grand Canyon West *Source: Grand Canyon Resort*

GCW is about 21 miles from the electrical grid so current energy is generated from individual generators at each site. A 15 kW and 17.5 kW solar array are also available but not in use due to past hindrances. It is believed that this separate on-site energy generation has contributed to GCW's profitability struggle. As such, a new distribution and generation system has been designed.

The new centralized 20.8 KV generation and distribution systems will include "…three new EPA compliant 750 KW Caterpillar Diesel Generators…with up-to-date environmental controls and up-to-date voltage and frequency control technology" (TTG Engineers, NA, p. 4) and existing solar arrays as "feeder points" (p. 4). This microgrid will be centralized to operate in a more efficient manner as loads and capacity are better matched; resulting in 15-20% increase in efficiency and about $100,000 annual fuel cost savings with diesel fuel at $3.87 per gallon (Schmitt and Davidson, 2013). Efficiency also reduces emissions and will improve the Grand

Canyon Class I air shed. 7.6 miles of underground cables will distribute the energy, in conjunction with a step-up and step-down transformer. Tying to the Regional Electrical Grid is also projected in the future, where the diesel generators will be used as back up and the PV produced energy will offset energy from the grid (Schmitt and Davidson, 2013).

CONCLUSIONS

The microgrids at the Ramona Band and soon to be Hualapai Tribe have benefitted and will benefit both tribes, not only for the reasons listed previously but also in economic development and diversification. The microgrids have and will create energy access to the tourism facilities in different ways, as microgrids are context dependent - both facilities have different needs, are in different locations, and use different energy sources. It should be noted that microgrids are not all the same and need to be planned accordingly.

Furthermore, planning ahead is essential when thinking about implementing a microgrid. Reggie Agunwah stated that "small microgrid[s] are not economically viable in certain circumstances because of the grid legacy so outside and diverse funding is needed put together the power systems" (personal communication, July 24, 2013). Several funding sources were garnered to purchase the system. In addition, having a future idea/plan will help to forecast costs and funding.

Education is key to the success of microgrid operations. Continuous community education on energy efficiency and use is important because off-grid microgrid systems that depend on renewable energy generate limited energy and systems can fail if they aren't used properly. Additionally, microgrids have more components involved than renewable energy systems alone so education and training on operations and maintenance are pertinent. Both types of education will build the capacity of tribal members' energy knowledge.

Lastly, the microgrid is enhancing tribal sovereignty. The overall tribal economy benefits from keeping money from leaking out of the tribe. Mr. Agunwah states "with no monthly utility bill, that money stays on reservation and gives the tribe independence after upfront costs are made" (personal communication, July 24, 2013). Tribes could also secure their future further, as microgrids secure an energy future.

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