Best Practices for Microgrids Applied to a Case Study in a Community

Edison Parés-Atiles, *Member, IEEE, Efraín O'Neill-Carrillo, Senior Member, IEEE, Fabio Andrade, Member, IEEE*

***Abstract*— Microgrids, especially renewable-based, represent an opportunity to increase sustainability and resiliency in places prone to natural disasters. The aftermath of hurricane María accelerated the discussion in Puerto Rico about supporting microgrids as an energy policy and strategy to build a different power grid. This paper presents an overview of microgrid literature relevant to Puerto Rico and it is used to identify best practices. The paper also describes a recommended process for feasibility studies needed to develop a community microgrids based on distributed energy resources (DER). An example applying this process to an actual community wraps up the paper.**

***Index Terms*—Microgrids, renewable energy, distributed energy resources**

I. Introduction

In 2007 the government of Puerto Rico (PR) created the regulation to interconnect generators to the electrical distribution system of the PR Electric Power Authority (PREPA). This regulation established the requirements and the process for the installation and operation of distributed generation systems (DG) to interconnect with the electric distribution system. Its purpose was to promote the use of renewable energy, guaranteeing the reliability of the electrical system and the safety of the employees, customers and equipment of PREPA.

After hurricane Maria, the majority of persons who had installed a photovoltaic (PV) system without an energy storage system, realized that their panels on their rooftops did not solve the problem of lack of electricity, as these systems work only when the PREPA system is energized. People of PR suffered for several months the agony of not having electricity in their homes. Currently most people, who request a PV system installation, also ask for an energy storage system.

On October 27, 2017, the Puerto Rico Energy Commission (CEPR) began an investigation concerning the state of Puerto Rico's electrical system as result of Hurricane María. As a result of the damages to the electrical system and considering the critical role of the electric service in the economic development, the Commission determined that the restoration of electric service was one of the main objectives in the short term.

On May of 2018, the CEPR Proposed the Regulation on Microgrid Development.

Edison Parés Atiles, Efraín O'Neill-Carrillo, and Fabio Andrade are with the Electrical and Computer Engineering Department, University of Puerto Rico, Mayaguez (corresponding e-mail: oneill@ieee.org).

The Final Microgrid Regulation sets the legal and regulatory framework required to promote and encourage the development of microgrid systems in Puerto Rico. This regulation enables customer choice and control over their electric service, increases system resiliency, fosters energy efficiency and environmentally sustainable initiatives and spurs economic growth by creating a new and emerging market for microgrid services.

II. Literature Review

Community energy projects are common in Europe. There are diverse definitions of community energy depending on a government's energy policies to support distributed energy resources and also depending on the social, cultural, political contexts and energy market designs. Denmark and Germany are pioneers in community energy generation. In the U.K. community energy can refer to community initiatives focused on reducing energy use, managing energy better, generating energy or purchasing energy. These projects or initiatives share an emphasis on community ownership, leadership or control where the community benefits [1]. The most common community energy projects in the U.S. are solar PV systems that serve communities. Community solar systems have a great potential in fossil-fuel dependent countries that import their fuels. Thus, all possible modes of solar communities should be allowed. But strategies and models are context-dependent [1].

A solar community could be transformed into a microgrid if it has enough local energy resources to meet the minimum demand [2]. Microgrids are a promising alternative [3], [4], not only to increase sustainability through renewable energy use, but also to increase resiliency to face natural and human-made threats to the electric infrastructure.

Some of the microgrid technical issues that need to be solved include power unbalance, frequency vs active power control, voltage s reactive power control, disturbances due to topolo-gical changes during transitions, islanding and protection [5].

Besides technical challenges, microgrids need to overcome social, and legal obstacles to become a key component in the transition to a sustainable energy future. Societies must plan ahead and decide on the best microgrid architecture that better addresses their specific needs [4]. A key obstacle is that most regulators still do not understand the complexities of microgrids. However, many do understand that microgrid applications are not all the same especially regarding regulatory aspects such ownership and business practices [6]. These ownership and business issues are particularly important to address in community-based energy projects. For this type of project personal relationships among participants are essential because of the strong agreements that need to be reached regarding rights and responsibilities of the shared system. Furthermore, since initial installation investment is commonly not done by the community [7], community members need to present a unified effort to bring in the needed funding [8].

A. *Feasibility Study Guidelines*

The following steps [9] are recommended when conducting a feasibility study to develop a community microgrid:

1. Set the project goals. Is the goal to maximize reliability? Cost savings? Business growth? Should the project be built in phases?
2. Organize, educate core stakeholders. Who are the potential champions, stakeholders and authorities who will have a say in this process? Should a steering committee be appointed? How can these parties be educated and organized?
3. Identify project site. Where are reasonably large pockets of consistent energy demand? Are there large energy users in these pockets who can anchor a project?
4. Conduct 1st level screening study. Is this project technically feasible? Is this site appropriate?

The collection of data is the initial basis of a feasibility study, and should include the following:

- House data which should include the house owner's information, copy of the latest utility electricity bill, House location coordinates, Utility meter number, Diagram with the roof measurements, and pictures of the roof and the utility meter.
- Demand Profile Data. Professional experts should go the site with technical personnel from the community to collect real time measured data from certain types of houses by means of a power analyzer. This is done to determine the typical behavior of the daily load profile of the community. From the profile, it is possible to obtain the daily consumption (kwh) during sun hours, the daily consumption (kwh) during the night, and the maximum power demand. This data may further be used to generate a typical load profile of the community and establish parameters for the design
- Topology of Community Electrical Network. The data of the topology will determine which electrical system configuration applies to the microgrid project. According with standard IEEE 1547.4 [11], there are a variety of operating configuration for intentional island that incorporate distributed resources (DR).

The social and institutional components are vital inputs necessary for the sustainability of projects. This is the reason why the proposed methodology considers especially significant that these energy projects contribute to the local social capital, through a community participation that fosters empowerment and appropriation by the benefited local communities [10].

For empowerment to occur, governments must provide a system of administrative democracy where institutions are given autonomy by the government to choose their own leadership. This is a way to decentralize and depoliticize institutions. From the point of view of energy, this approach can be very useful in community-based energy strategies since citizens and communities are better acquainted with local needs and thus can provide vital information for local energy decisions and processes [1].

B. *Distributed Resources Island System Configuration*

1) *Local Electric Power System (EPS) island (Facility Island)*

The DR island system is formed from generation and load normally served within a customer facility. This is also called a facility island. The DR island system has only one PCC with the area EPS. Facility DR can be operated to serve the load of the facility when there is a loss of the area EPS [11]. This configuration applies to isolated houses which cannot be connected to other houses due to the high electrical distances.

2) *Secondary Island*

One or more DR and multiple customers connected to the secondary side of one distribution transformer. There may be multiple secondary islands on a single distribution lateral. For example, community energy storage units can be deployed in secondary islands. In these systems, an area EPS-owned storage device is connected on the secondary side of the distribution transformer with multiple customers connected to the secondary. Other forms of DR may be installed on the secondary island along with community energy storage [11].

This configuration applies when connecting a group of houses with short electrical distances in between, at the substation bus. The concept consists of interconnecting a group of houses, at 240 volts underground secondary voltage. This group is named a secondary voltage microgrid (SVM).

3) *Lateral Island*

The island is formed from loads normally served from a lateral on a distribution circuit. The generation can be operated to serve the load of the island when the lateral switching device (e.g., the breaker, recloser, or sectionalizer) opens [11]. This configuration applies to a group of secondary voltages microgrids.

C. *Monitoring and control in a microgrid*

In a community microgrid, it is necessary for the customers to have knowledge of everything that is occurring within the microgrid. This can be solved through an Energy Control Center (ECC), which should integrate a communications and control system called SCADA (Supervisory Control and Data Adquisition). The traditional SCADA system is based on gathering, processing, and analyzing real-time data from the field. The social SCADA concept as the sum of the social component (i.e., the community) and traditional SCADA applications. Social SCADA contributes to achieve a more resilient community, which means an increased capacity of adaptation to changes over time using local resources.

The social component facilitates community participation in the decision-making process for the development of the energy system. The main aspects to consider are: primary resources, generation technologies, communication networks, electricity consumption, operation and monitoring and control [13][14].

For a preliminary estimate of key financial measures, such as the payback period, LCOE, and net present value, the System Advisor Model software (SAM) may be used. For a Community

Microgrid, one of the key financial measures that is important to the customer is the Levelized Cost of Energy (LCOE).

The Levelized cost of energy (LCOE) is one of the utility's primary metrics for measuring the cost of electricity produced by a generator. It calculates the value of the unit's annualized total cost divide by its estimated annual energy output. As a financial tool, LCOE is very valuable for the comparison of various generation units. A low LCOE indicates a low cost of electricity generation. For a usual power plant, the future fuel price is uncertain and largely depending on external factors, while e renewable energy resource has zero fuel cost [16].

III. Case Study

An organized community determined to conduct a feasibility study to develop a renewable energy production system, configured as a microgrid system. In the first phase of the feasibility study, members of the community participated in the data collection process. A group of community members was selected, trained and supported in the collection of data for 223 houses. This participation is of utmost importance, so the community takes an active participation in the process of the development of the community microgrid.

The case study was based for a community located in a rural area, in the east of PR, of around 17 km^2 with 223 houses to be studied and approximately 3,000 residents, according to the United States census Beareau. The electric power for the entire community comes from a PREPA substation, through 8,320-volt distribution feeder.

A. Data Collection

The collection of data by community members is an important step, since they are the ones who know the neighborhood and it is the way to start participating in the technical and social aspect of the project. Active members of the community who will participate in the data collection, should be trained by professional experts, on the data they need to collect from each household. These professional experts will also provide support in the data collection process.

A site survey form was supplied to the community data collectors, which specifies the data needed to be collected. After all the data was validated, it was then organized and tabulated. Each house was given an ID and each sector a number or name as well. See Table 1 for an example of the tabulated data. The "CL1" stands for the cluster or sector, and the "001, 002, etc.," stands for the number of the house in that cluster or sector.

Table 1: Example of tabulated data

ID	Customer	Physical Address	Coordinates Location Pin Link	Coordinates	Utility Meter Number	Roof Area (ft^2)	Peak Daily Consumption (kwh)	Daily Average Consumption (kwh)
CL1-001	John Doe	#1, First Road, Somewhere	https://goo.gl/maps/WfV	18.134972, -66.07806	55228468	2634.24	16	11.25
CL1-002	John Smith	#4, First Road, Somewhere	https://goo.gl/maps/qNfy	18.136017, -66.031053	18746041	5300	3	2.17
CL1-003	Jane Doe	#15, 2nd Road, Somewhere	https://goo.gl/maps/iSvE	18.13944, -66.079261	25811273	1512	9	7.83
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
CL1--00N	Jane Smith	#9, 2nd Road, Somewhere	https://goo.gl/maps/fv1	18.78650, -66.67907	16524112	2100	13	11.50

Experts went to the site to collect real time measured data from certain types of houses with a power analyzer equipment. This data generated a typical load profile of the community and established parameters for the design (Figure 1).

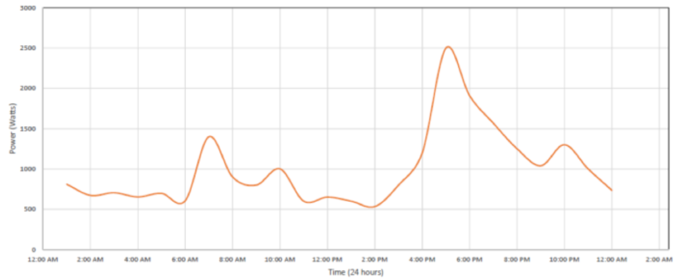

Figure 1: Example of Typical Load Profile

To determine the community's existing utility configuration, information about the electrical infrastructure had to be gathered. The governmental geographic data portal contains a wide variety of geographical data of different government and public agencies, including PREPA's electrical infrastructure. This data is downloaded and then plotted using a geographical information system (GIS) as shown in figure 2.

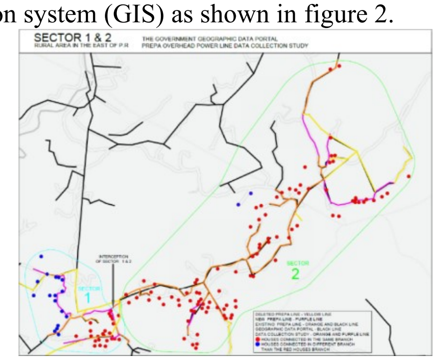

Figure 2: Example of infrastructure in the community

B. Secondary Voltage Design

PV panels would be installed at the houses with roofs suitable for this use and the batteries would be installed in a single site of each SVM, in such a way as to produce enough renewable energy daily and storage capacity for each house. See figures 3 for an example of Secondary Voltage configurations.

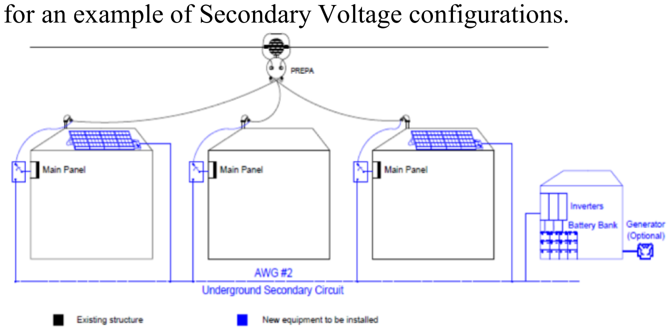

Figure 3: Example of Secondary Voltage Back-up Configuration

Using the coordinates tabulated and entered in the QGIS System, we can group the houses in SVM's. To select the houses that will be participating inside the secondary voltage microgrid, the voltage drop formula was used to determine the maximum distance available from the BESS, without surpassing a 3% of voltage drop. Using a #2 AWG cable, it was determined that the furthest house connected, should not exceed 1200 ft. See figure 4 for an example of a map, grouping the houses in different SVM's for these sectors. Each sector or cluster can be composed of different groups of SVM. The distances for the Secondary Voltage underground circuit were calculated using the QGIS after plotting and grouping the

SVM's. The QGIS also offers us this tool to measure distance between desired points or locations.

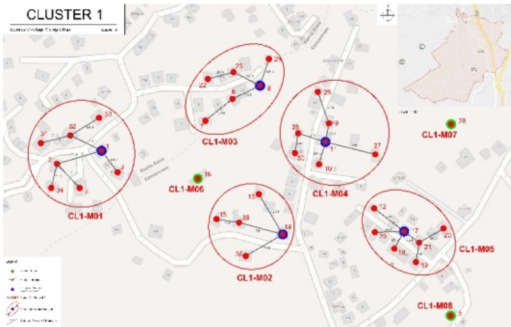

Figure 4: Example of Secondary Voltage Migrogrids Configuration map

For the selection of the equipment, the Hanwha Q.Cells Q.Peak-G4.1 PV module with a capacity of 300 Watts was chosen. This module is monocrystalline, which has higher performance that polycrystalline modules, this also means that even though the module has a high-power capacity, it is smaller because it has less solar cells, thus occupying less area in the roof than a polycrystalline module of that same capacity.

For the grid tied inverter, the Enphase IQ 6 microinverters were chosen. For this particular case studied, the inverter chosen was the Conext 6848XW.

The batteries chosen were Full River DC260-12 Sealed AGM Battery, with a 7-year warranty. This battery has a high performance and longer warranty while compared to others in the market in the same price range.

The equipment sizing analysis was done following industry practices [17]. For the case studied, the median value of the daily consumption gathered from the community's electricity bill was used, which in this case was 12 kwh. The load profile graph generated by the power analyzer indicated that the typical maximum power demand is 2.5 KW. The average energy consumption during the night is 6 kwh (8 kwh dc) measured from the REAL DATA COLLECTION process of the case studied. Four (4) batteries of 12 V, 260Ah and 8000 Wdc of daily energy consumption was used in the battery sizing tool worksheet. The calculation of the Depth of Discharge (DOD) was 54%. This DOD value is high and may affect the life cycles of the battery. (DOD 0.54 means approx. 1250 life cycles, equivalent to 3.5 year of continuous use). To compensate for this, there are two options: to use a generator or to add another battery bank of 4 batteries. (With 8 batteries, the DOD is 27% means 2,300 life cycles, equivalent to 6 years and 4 months). This is to be decided by the investors of the project.

For the case studied, using the 12-kwh consumption and a battery efficiency of 90%, it was determined that 12 PV modules of 300 Watts each were needed per house. Since not all the houses in the SVM have available or usable roof space for the PV panels, the quantity of the total PV Panels needed for all the houses in each SVM have to be distributed in the available roofs in the SVM. Table 2 shows the result of the distribution of equipment in each house in each microgrid.

Table 3 show the costs of the equipment and materials from different vendors. Also, it includes the costs of the design, engineering, permits, installation and commissioning.

Table 2: Example of Secondary Voltage Microgrid Equipment Distribution

ID	Client	Daily Avg Consumption (KWh)	Yearly Avg Consumption (KWh)	Number of PV Panels (300W)	Inverter On Grid (240W)	Inverter Battery-based (6.8KW)	Batteries (12V@260Ah)
Cluster CL1	*Cluster 1*						
Microgrid CL1-M01							
CL1-001	John Doe #1	11.25	4,050	24	24	3	24
CL1-008	Jane Smith #4	3.83	1,380	14	14	0	0
CL1-033	John Doe #17	13.20	4,752	11	11	0	0
CL1-034	John Doe #18	15.00	5,400	14	14	0	0
CL1-035	John Doe #19	6.42	2,310	0	0	0	0
CL1-038	Jane Smith #18	10.17	3,660	9	9	0	0
Summary for 'Microgrid' = CL1-M01 (6 detail records)							
Sum		59.87	21,552	72	72	3	24
Microgrid CL1-M02							
CL1-004	John Doe #4	5.33	1,920	20	20	0	0
CL1-009	John Doe #5	7.33	2,640	0	0	0	0
CL1-010	John Doe #6	15.25	5,490	13	13	0	0
CL1-018	John Doe #10	10.67	3,840	40	40	4	36
CL1-020	John Doe #12	8.58	3,090	0	0	0	0
CL1-025	John Doe #13	10.92	3,930	10	10	0	0
CL1-032	Jane Smith #16	18.60	6,696	16	16	0	0
CL1-036	John Doe #20	3.75	1,350	9	9	0	0
CL1-039	Jane Smith #19	10.00	3,600	0	0	0	0

Table 3: Secondary Voltage Microgrid Tabulated Costs for a cluster

Cluster 1 SVM Cost				
Item	Quantity	Unit	Cost/Unit	Cost
PV Panel (300 W)	521	Watts	0.62	$ 96,906.00
Microinverter (240 W)	521	Watts	0.48	$ 60,019.20
Battery Based Inverter (6,800 W)	22	Watts	0.52	$ 77,792.00
Battery (3,120 Wh)	168	Watts-hour	0.22	$ 116,761.88
Sytem Racking (156.3 KW)	1	KiloWatts	150	$ 23,445.00
Equipment Installation including B.O.S. (156.3 KW)	1	KiloWatts	300	$ 46,890.00
Underground Circuit (4754 ft)	1	feet	37.66	$ 179,035.64
Engineering and Design (156.3 KW)	1	KiloWatts	150	$ 23,445.00
Total				$ 624,294.72

If the study of the configuration in the existing electrical network concludes that all the houses of a sector are connected in different branches of the electrical system, then it is necessary to develop an aerial electrical network, to convert the SVM system into a network with primary voltage, which is called Primary Voltage Microgrid (PVM). Figure 7 shows an example of a PVM Configuration.

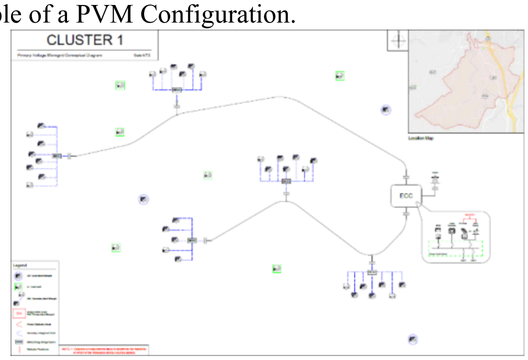

Figure 7: Example of a Primary Voltage Microgrid Configuration.

C. *Primary Voltage Design*

This phase evaluated different alternatives of primary voltage power line to interconnect the SVM with the generation control center (ECC).

First, the installation of an underground system at the level of a primary voltage of 4,160 volts, along with the materials and installation costs. These costs are preliminarily calculated using typical actual unit price for primary voltage underground circuits on the industry. The distance for the lines calculation, is based on an approximation of the distance using the geographical map of the site. The primary voltage power line would follow the path of the roads' right-of-way. After all the calculations of the distances were completed, then it was necessary to solicit the costs of these equipment from different vendors. Table 4 shows the costs for the Primary underground circuit for the case studied, including installation.

Table 4: Example of costs for a primary underground Circuit

Cluster	Total underground feet	Transformer Quantity	Cost of underground trench and conduit	Cost of installed primary wiring	Cost of installed transformers	Total cost for underground line installation
Cluster 1	5704	6	$444,341.60	$233,864.00	$22,350.00	$700,555.60

Second, to have exclusive use of the utility electricity grid, under an agreement of a monthly rent payment. For this alternative is necessary to have the amounts of poles, distances of electrical lines, transformers in each sector accounted by the professional experts along with the community technical personnel in the data collection process. This can be done using the Solocator app. The rental costs are based in the "Monthly Infrastructure Lease Fees PREPA" proposed by the CEPR [12]. Table 5 shows the costs for the case studied.

Table 5: Example of rent costs for utility equipment

Cluster	Poles	Overhead Conductor	Line Xformer	Total KVA Xformer	Service Circuits	Quantity of meters	Payment/month
Cluster 1	47	8035	12	482.5	42	42	$1,451.17

Third, the Installation of 4,160 volts overhead power lines. Costs of installations for poles, lines and transformers were calculated using PREPA construction standards AC-A7-3 [18] and standard PREPA URD-10 [19]. For the purposes of a feasibility study, the distance for the lines calculation can be based an approximation using the geographical map of the site. For the construction phase of the project, the right-of-way of the line should be measured and certified by a Surveyor. Table 6 shows the costs for the new primary aerial line for the case studied.

Table 6: Example of costs for a new primary aerial line

Cluster	Pole Quantity	Total aerial feet	Transformer Quantity	Cost of installed pole	Cost of installed primary wiring	Cost of installed transformers	Total cost for aerial line installation
Cluster 1	38	5704	6	$133,000.00	$14,260.00	$16,500.00	$163,760.00

From the study, the most viable alternative is the new primary aerial line, since it is the most economical with a shorter installation time.

It is to be understood that microgrid policies are unavoidably related to distributed energy polices and precisely renewable energy [20]. Therefore, as part of the case study, an economic analysis was made using SAM. If we take as a case #1, a single house consuming 12 KWh, 10kWh of battery storage and 3.6 KW of solar power. As a case #2, 8 single houses are connected through an underground secondary voltage microgrid, the LCOE and Net Capital Cost will spike to 25.13 ₵/KWh and $98,340 (see table 7). When both cases are compared, an initial incentive may be needed in order to justify the development of the secondary voltage microgrid. The case #3 contains the same characteristics as case #2 but adding an initial incentive of 35%, as expected, the LCOE and Net Capital Cost drastically reduced to 14.75 ₵/KWh and $63,921 (see table 7). Furthermore, if an additional 10% of initial investment is added, the LOCE will further reduce to 11.78 ₵/KWh.

Table 7: Financial Parameters for Three Different Cases

Case #	Description	Annual Energy	LCOE (nominal)	NPV	NCC
1	Single House without incentives	5,998 KWh	13.17 ₵/KWh	$795	$6,879
2	SVM of 8 houses without incentives	47,848 KWh	25.13 ₵/KWh	-$35,244	$98,340
3	* SVM of 8 houses with incentives	47,848 KWh	14.75 ₵/KWh	$0	$63,921

From this preliminary economic analysis of the case studied, it was determined that for the project to be economically viable, it needs incentives of around 35% of the capital cost.

IV. Conclusions

This paper presented an overview of relevant microgrid literature, the recommended practices for microgrid development and a potential application of those practices to an actual community in Puerto Rico. It is recommended to start with a pilot project no larger than 40 houses, that should include the secondary voltage microgrid and, if the community has the economic resources, they must include the energy control center (ECC) with the primary voltage network.

The microgrid entails operation with high voltage lines and very sophisticated equipment. It is necessary to institute a technical education program covering areas such as technical installation, operation and maintenance of electrical systems. To have a system that can be sustained working for long years, it is necessary to have people with technical expertise that can operate and maintain the system.

References

[1] E. O'Neill-Carrillo, E. Mercado, O. Luhring, I. Jordán. "Local Socio-Economic Development through Community-Based Distributed Energy Resources," IEEE Inter. Symp on Tech. & Society 2018, Washington DC.

[2] E. O'Neill-Carrillo, I. Jordán, A. Irizarry-Rivera, R. A. Cintrón. "The Long Road to Community Microgrids," IEEE Electrification Magaz, Dec. 2018.

[3] M. S. Mahmoud, M. Saif Ur Rahman and F. M. A.L.-Sunni, "Review of microgrid architectures – a system of systems perspective," IET Renewable Power Generation, vol. 9, no. 8, 2015, pp. 1064-1078.

[4] A. Hirsch, Y. Parag, J. Guerrero. "Microgrids: A review of technologies, key drivers, and outstanding issues," Renewable and Sustainable Energy Reviews, vol. 90, 2018, pp. 402-411.

[5] P. Gaur and Sunita Singh, "Investigations on Issues in Microgrids," Journal of Clean Energy Technologies, vol. 5, no. 1, 2017, pp. 47-51.

[6] Ashwini Kumar, Murari Lal Azad. "Challenges in Recent Microgrid Systems: A Review," International Journal of Advances in Engineering & Technology, vol. 8, no. 2, April 2015, pp. 203-210.

[7] D. Horvath, R. Szabo. "Evolution of photovoltaic business models: Overcoming the main barriers of distributed energy deployment," Renewable and Sustainable Energy Reviews, vol. 90, 2018, pp. 623-635.

[8] J. Leader, Financing Community-Based Solar Projects: Case Studies from the Field, The Smart Electric Power Alliance (SEPA), May 2018.

[9] Community Microgrids: A Guide for Mayors and City Leaders Seeking Clean, Reliable and Locally Controlled Energy, MG Knowledge, 2015.

[10] K. Ubilla and G. A. Jiménez-Estévez, R. Hernádez and et all, "Smart Microgrids as a Solution for Rural Electrification: Ensuring Long-Term Sustainability Through Cadastre and Business Models," IEEE Transactions on Sustainable Energy, vol.5, no.4, Oct. 2014.

[11] IEEE Guide for Design, Operation, and Integration of Distributed Resource Island System with Electric Power System, IEEE, Std 1547.4, 2011.

[12] Puerto Rico Energy Commission. Regulation on Microgrid Development. P.R. CEPR-MI-2018-0001, May. 2018.

[13] G. A. Jimenez-Estevez, R. Palma-Behnke and D. Ortiz-Villalba "It Takes a Village: Social SCADA and Approaches to Community Engagement in Isolated Microgrids." IEEE Power and Energy Magazine, 2014, pp.60-69.

[14] C.A. Canizares. "Trends in Microgrid Control, IEEE-PES Task Force on Microgrid Control," IEEE Transactions on Smart Grid, Vol. no. 4, pp 1906 and pp 1909, July 2014.

[15] Muni-Fed – Antea Group Energy Partners, LLC, The Port of Long Beach. Microgrid Technology White Paper. Long Beach, CA, Aug. 2016, pp. 15.

[16] C. Yuan, M. S. Illindala. ''Economic Sizing of Distributed Energy Resources for Reliable Community Microgrids''. IEEE Power & Energy Society General Meeting, Vol. 1, pp. 1, Aug. 3, 2017.

[17] Dunlop, J. Photovoltaic systems. 3rd ed. American Technical Publishers, Inc., Orland Park, IL. 2012.

[18] PR Electric Power Authority – Transmission and Distribution Directorate. Patrones de Construcción de Distribución Aérea. P.R. AC-A7-3, Jun. 1986.

[19] PR Electric Power Authority – Electric Distribution Division. Manual de Patrones de Distribución Soterrada. P.R. URD-10, Jan. 2000.

[20] Amajad Ali, Wuhua Li, et all, "Overview of Current Microgrid Policies, Incentives and Barriers in the European Union, United States and China". Sustainability, Vol. 9, Jun. 29, 2017. pp. 1-28.