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Article

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A Review: Integration of Renewable Energies in the Sustainability of the Electric Distribution Grid

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ABSTRACT

This Article submits a review of the integration of renewable energies in the contemporary distribution of generated energy. A technological supervision is implemented to observe in a systematic manner the behavior of state of the art technologies in renewable energies, in the search of energetic sustainability, making an analysis of the distribution of the most representative Microgrids at world level. It is to be noted, the great inclusion of energy obtained through solar panels, and Eolic generators. However, there is a great participation of generators from diesel vapor, and gas; while in the storage system batteries are predominant, and sometimes, flywheels and supercapacitors surface. These results are possibly due to the promotion and experience of including new techniques and use of energy resource methodologies.

Keywords: Renewable Energies, Distributed Generation, Microgrid, Generation Systems, Energetic sustainability.
JEL Classifications: Q01, Q4, Q42

1. INTRODUCTION

The use of renewable energy sources has stopped being a possibility for generating their own energy, to becoming a need of the countries to ensure the reliability of supplied electric energy by other means of generation (Rueda-Bayona et al., 2019). The inclusion of renewable sources is also due to the significant reduction in Carbon Dioxide emission (CO2), since there is no burning of fossil fuel (Muñoz et al., 2014). Energy demand increases every day, there are new constructions and many buildings, commercial, industrial or residential, and sometimes, there is a need for energy in non-interconnected zones (NIZ), which complicates and raises the prices of connecting to the electric grid (Cabello-Eras et al., 2019).

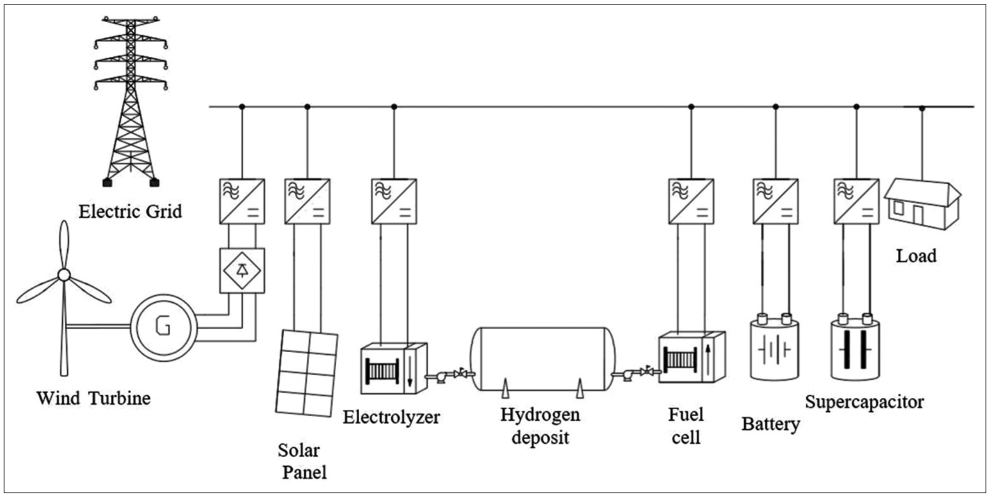
Starting from the concept of Microgrid as a small scale distribution grid, constituted by a mix of distributed energy sources, loads, and generally with the use of storage equipment, establishing a distributed generation system that works interconnected in order to supply electricity for the local demand, increase energetic sustainability and reliability of the electric power, besides being self-sufficient and operating in an isolated mode when necessary (Ospino and Ortega, 2013; Gui et al., 2017, Tolón, 2013; Shuai et al., 2016). On Figure 1 it can be seen an example of microgrid, in which several energy generations sources and storage technologies are integrated (Bordons et al., 2015).

The use of Microgrids to generate electric power offers great advantages, among which (Nam et al., 2017) emphasizes: Energetic efficiency, Reduction of greenhouse gas emissions, a fact that was remarked at Parties Conference held in Paris in 2015, the 21st of this kind, known as COP21; an also, the increase of supply security (Tobin et al., 2018).

2. REVIEW OF SCENARIOS OF RENEWABLE ENERGIES IN MICROGRIDS

The impact of distributed generation in the world of electric power drove cities with state of the art technology to develop

Figure 1: Microgrid example



their Microgrids. Reasons like the improvement of energy quality, supplying hard to reach areas, besides, the benefits of low pollution with renewable sources help promote their development.

A great implementation of Microgrids can be found with models that sometimes differ in the technology used to generate energy, some implement only renewable sources and others combine them with conventional sources, whether using storage systems of different types to ensure power supply.

To revise Microgrids, the information of each is organized on tables, with their respective name and country of installation, to be able to observe in a simple manner which technologies are implemented on them. Two tables were set, on Table 1 are encompassed the Microgrids of Europe, Oceania, Asia and part of North America, and on Table 2, is condensed the corresponding information to the second part of North America and the rest of the American continent.

On Table 1, Germany stands out for having implemented three Microgrids, the first one is The Residential Microgrid of Am Steinweg in Stutensee, with a ring shaped structure connected to the medium voltage transmission grid, with a 68,8 kW capacity. Its generation sources are photovoltaic installations with 35 kW nominal rating, besides an optional 28 kW of co-generating power and a storage system based on batteries, to feed residential demand(Sood and Abdelgawad, 2019); the second is Mannheim Microgrid, which has 30 kW of photovoltaic generation (Hatziargyriou, 2014); and in Kassel, DeMoTec test microgrid system, with 200 kW total capacity, fed by two diesel generators, a photovoltaic and an eolic generator, besides two battery banks (Arango and Álvarez, 2013).

On Table 1, Greece is also noted for having Microgrids, like Kythnos Island Microgrid, with 10 kW of photovoltaic generation and a 9 kVA diesel generator, besides a storage system constituted by batteries and 12 houses as load (Hatziargyriou, 2014). Meltemi Microgrid, located on a beach camping with 220 country houses, used mostly for summer breaks. In this field there is an autonomous microgrid with photovoltaic panels and an eolic generator, both in combination with a fuel battery and an interconnected system, constituted by a series of distributed generators, including solar panels, eolic generator, a diesel generator and a storage system made with two batteries (Papaioannou et al., 2011). The National Technical University of Athens (NTUA) developed another microgrid, Microgrid NTUA, scaled, composed by two photovoltaic generators with 1,2 kW power, a 1 kW eolic turbine, with a battery storage system, controllable and controlled load of interconnection to the local BT grid (Bayindir et al., 2014).

Spain has an installed capacity of 22,845 MW Eolic energy and 4,428 MW photovoltaic power. It can be found on Table 1 with Smartcity Málaga. Microgrid on actual scale located in a laboratory that uses generation by photovoltaic technology, microeolic, trigeneration, cogeneration, producing medium and low voltage (13 MW and 95 kW respectively) (Grids, 2011; Josa, 2011). On the other hand, the Labein research institute has implemented a microgrid, Microgrid Labein, interconnected to the electric grid and constituted by: photovoltaic generators, a single phase 2,2 kW and a three phase 3,6 kW, two diesel generators (55 kW), a 50 kW microturbine and a 6 kW wind turbine. Integrating electrochemical battery, ultra-capacitor and Flywheel for storage: Tolón, 2013.

Holland, located on Table 1, with a microgrid named Bronsbergen Holiday Park Microgrid, in an amusement park. It feeds 208 homes and generates power by solar panels with a peak of 315 kW although with a maximum load of 150 kW (Arango and Álvarez, 2013).

Ireland also has a Microgrid, Nimbus Microgrid Testbed, shared with Ireland United Technologies Research Centre Ireland Ltd. (UTRCI), Cork Institute of Technology (CIT) and National Sustainable Building Energy Testbed (NSBET). It has a 130 kW (50 kW electric and 80 kW heat) cogeneration system, eolic generation (12 kW), thermal storage (Phase-Change Material, PCM, and water), and a battery storage system. Applied to residential type loads (Bayindir et al., 2014).

Italy, with the Microgrid CESI RICERCA DER test microgrid, in Milan, constituted by a 350 kW test bench in low voltage

Table 1: Microgrid demonstrations in Europe, Oceania and Asia

Name/Country	PV	Solar Thermal	Wind	Fuel Cell	CHP	CCHP	Hydro	Diesel (D)/Steam (S)/Gas (G)/Biomass (BM)/Biogas (BG)	Driven motor generator	Battery (B) Flywheel (FW) Ultracapacitor (C)	Commercial (C) Industrial (I) Residential (R)	Motor	Static
Steinweg/Germany	×	-	-	-	×	-	-	-	-	B	R	-	-
DeMoTec/Germany	×	-	×	-	-	-	-	-	-	B	C–R	-	-
Wannheim/Germany	×	-	-	-	×	-	-	-	-	B	R	-	-
Kythnos/Greece	×	-	-	-	-	-	-	D	-	B	R	-	-
NTUA/Greece	×	-	×	-	-	-	-	-	-	B	-	-	×
Meltemi/Greece	×	-	×	×	-	-	-	D	-	B	C–R	-	-
Málaga/Spain	×	-	×	-	×	×	-	-	-	-	C–I–R	-	-
Labein/Spain	×	-	×	-	-	-	-	D	×	FW–C	C–I–R	-	-
Bronsbergen/Holland	×	-	-	-	-	-	-	-	-	B	R	-	-
Nimbus/Ireland	-	-	×	-	×	-	-	-	-	B	R	-	-
CESI/Italy	×	×	×	-	×	-	-	D	-	B–FW	R	-	-
Univ Manchester/United Kingdom	-	-	-	-	-	-	-	-	×	FW	-	-	×
AusNet/Australia	-	-	-	-	-	-	-	D	-	B	R	-	-
Marble Bar/Australia	×	-	-	-	-	-	-	D	-	-	R	-	-
Aichi/Japan	×	-	-	×	-	-	-	G–BG	-	B	C–I	-	-
Kyoto/Japan	×	-	×	×	-	-	-	BG	-	B	R	-	-
Hachinohe/Japan	×	-	×	-	-	-	-	G–BM	-	B	C–I	-	-
Sendai/Japan	×	-	-	×	-	-	-	G	-	B	C–I–R	-	-
Miyako/Japan	×	-	×	-	-	-	-	D–G	-	B	C–I–R	-	-
Shimizu/Japan	×	-	-	×	-	-	-	G	-	B–C	C–I–R	-	-
HFUT/China	×	-	×	×	-	-	×	D	-	B–C	-	×	×
INER/China	×	-	×	-	-	-		G	-	B	-	×	×
Boston Bar/Canada	-	-	-	-	-	-	×	-	-	-	R	-	-

PV: Photovoltaic, CHP: Cogeneration, CCHP: Trigeneration

Table 2: Microgrid demonstrations in America, Part I

Name/Country	PV	Solar Thermal	Wind	Fuel Cell	CHP	CCHP	Hydro	Diesel (D)/Steam (S)/ Gas (G)/Biomass (BM)/Biogas (BG)	Driven motor generator	Battery (B) Flywheel (FW) Ultracapacitor (C)	Commercial (C) Industrial (I) Residential (R)	Motor	Static
Quebec/Canada	-	-	-	-	-	-	-	S	-	-	R	-	-
CERTS/U.S.	-	-	-	-	-	-	-	G	-	B	-	-	×
Mad River/U.S	×	-	-	-	-	-	-	D	×	B	C–I–R	-	-
Hawaii/U.S.	×	-	×	×	-	-	-	-	-	B	R	-	×
RIT/U.S.	×	-	×	×	-	-	-	BG	-	-	R	×	×
Palmdale/U.S.	-	-	×	-	-	-	×	G	-	C	C–R	×	×
Wal-mart/Mexico	×	-	-	-	-	-	-	-	-	-	C	-	-
UAM/Mexico	×	-	-	-	-	-	-	-	-	-	C–I–R	-	-
Bicentenario/Mexico	×	-	-	-	-	-	-	-	-	-	R	-	-
X-Calac/Mexico	×	-	×	-	-	-	-	D	-	-	R	-	-
Villas Carrousel/Mexico	×	-	×	-	-	-	-	-	-	B	R	-	-
Isla Margarita/Mexico	×	-	×	-	-	-	-	D	-	-	R	-	-
San Juanico/Mexico	×	-	×	-	-	-	-	D	-	-	R	-	-
EarthSpark/Haiti	×	-	-	-	-	-	-	D	-	B	C–R	×	-
Coco Torres/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Corriente Lira/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Kamana/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Pintada/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Portalupi/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Kayaska/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Wiwilí/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Y-Y/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Zopilota/Nicaragua	-	-	-	-	-	-	×	-	-	-	R	-	-
Jujuy/Argentina	×	-	-	-	-	-	-	D	-	-	R	-	-

PV: Photovoltaic, CHP: Cogeneration, CCHP: Trigeneration

(400 V), connected to medium voltage (23 kV) through a 800 kVA (Bayindir et al., 2014) transformer. It has the following generation technologies: eolic, diesel, biomass generator, photovoltaic, gas microturbine, fuel cells and a Stirling engine. It integrates storage technologies like Lead-acid batteries, zebra batteries and flywheels (Lidula and Rajapakse, 2011).

In the United Kingdom, University of Manchester ventures into Microgrids with a 20 kVA power system, Microgrid/Flywheel Energy Storage Laboratory Prototype. Which, as observed on Table 1, has a coupling between a synchronous generator and an induction engine, while its storage is based on flywheel technology (Lidula and Rajapakse, 2011).

In Australia, as seen on Table 1, the microgrid, SP AusNet, has a battery storage system and a 1 MW diesel generator system. A Microgrid that is a Pilot Project for the electric distribution grid of SP AusNet in Victoria, Australia (Mahieux and Oudalov, 2011). Another microgrid located in this country is Marble Bar, that started operating in 2010 by venturing into solar photovoltaic–diesel. It implements a grid stabilizer technology and energy management, to ensure that the maximum energy is obtained from panels while the sun is on view, reducing or turning off the diesel generation.

In regard to microgrids, Japan is one of the countries with more implemented demonstrations, as can be seen on Table 1, among them: Aichi microgrid Project–Central Japan Airport City, built as part of a demonstration project by New Energy and Industrial Technology Development Organization (NEDO), which supplies a total energy of 3716 MWh. The primary energy generation sources: a photovoltaic system with 330 kW capacity and fuel cells of different chemical composition (Molten Carbonate, Solid Oxide, Phosphoric acid), it uses a storage system with a sodium-sulphur battery (NAS), equipped with converters (12,22); Kyoto eco - Energy Project (Kyotango Project), executed by NEDO. Composed by five internal combustion engines, using biogas as fuel, for a total power of 400 kW, A MCFC fuel battery (Molten-carbonate fuel cells) with 250 kW power and a lead-acid battery, 50 kW photovoltaic system and a 50 kW power in wind turbines connected in remote locations (Lidula and Rajapakse, 2011; Rese, 2012); Regional Power Grid, Hachinohe.The generated energy comes from the following sources: four photovoltaic groups with a 80 kW total capacity, three 20 kW of power eolic generators and a power of 510 kW originated by tree gas turbines. It also has a storage system composed by a group of batteries, to make fast changes whenever not possible with the generators (Falahati et al., 2016); Sendai Microgrid, located in Sendai, has two gas engine generators, with 350 kW power, a 250 kW MCFC fuel cell, a 50 kW photovoltaic system and a battery storage system (Munoz et al., 2019); Shimizu Microgrid, has two gas generators (90 kW and 350 kW), a lead battery and a photovoltaic system (10 kW), using batteries and a supercapacitor to store energy (Amin, 2016); Miyako Island Microgrid, also stands out, considered as one of the great global microgrid projects, located in the city of Miyako. It has three installations equipped with the following sources: the middle west installation has a 5.000 kW gas turbine and three generators, two diesel, Miyako of 10.000 kW and Miyako #2 of 55.000 kW; In Karitama, north of the island, three wind turbines, one of 600 kW and two of 900 kW; also, southeast of the island, Fukuzato, has two wind turbines, each of 900 kW, one 4 MW photovoltaic installation and a group of batteries, NAS and lithium ions or LIB (Morozumi, 2015; Onodera, 2013; Tamaki et al., 2012).

China, Asian country that has a 123,86 GW accumulated installed capacity, mainly from eolic and photovoltaic sources (Jiang et al., 2015). Encompassing the microgrids, on Table 1 is shown the system located on Lab in Hefei University of Technology (HFUT) and composed by photovoltaic generation, a single phase of 10 kW power and a three phase with 30 kVA power, two three-phase eolic generation simulators, both of 30 kW, a fuel cell (5 kW) and a storage system with a battery bank and also, an ultracapacitor bank, some of its loads are; resistances, condensers, coils, AC y DC engines and other electronic loads (Xie et al., 2017). And the Microgrid in Taiwan, located on the testing bench of the Institute of Nuclear Energy Research (INER). A radial type Microgrid (500 kW), constituted by photovoltaic and eolic generation, gas generator and batteries (Lee et al., 2012).

On Table 1, is shown a Microgrid located in Canada, American country, where the fusion of two service companies Hydro Quebec and BC Hydro has implemented some planned microgrids on islands (Munoz, 2019). In the city of Boston Bar, is found BC Hydro Canada, arising as a response to the continual interruption of electric fluid, sometimes up to 20 h and as often as three times a year. The Boston Bar Independent Power Producer (IPP) has two 3,45 MW generators of hydroelectric energy and it is connected to one of the three power sources with a maximum charge of 3 MW; Hydro Quebec–Boralex planned islanding, related on Table 2, its power source is a gas generator, with peak power demand of 7 MW. These microgrids do not have storage system (Arango and Álvarez, 2013).

The United States has a large number of microgrids, not only at laboratory and test level but also in industrial parks. Generally, the photovoltaic generation system and batteries for storage is predominant. Some demonstrations in this country are found in Table 2: In Ohio, within the Consortium for Electric Reliability Solutions (CERTS), a microgrid consisting of sources based on static converters or inverters of 60 kW spurred by natural gas (Arango and Álvarez, 2013); Mad River Microgrid at Vermont with 280 kW installed at Northern's Industrial Park in 100 kW generator sets, a microturbine with 30 kW capacity, a photovoltaic generator and the possibility of island operation (Bayindir et al., 2015); Hawaii Hydrogen Power Park. The Power system at Kahua Ranch, Hawaii, part of the large Power Park Island, is a mix of wind, solar, fuel cell, and battery-based generation systems; In New York Microgrid test-bed at Rochester Institute of Technology (RIT), a composite installation of 5 kW of wind turbines, 46 kW photovoltaic, 100 kW of fuel cells, and a battery bank system. In addition, a heating/cooling system of eight geothermal wells, and a fuel cell of 400 kW.

The generated energy is used for construction lights, electrical outlets and for electric vehicle charge stations; the Palmdale microgrid in California. Composed of a 950 kW wind turbine, a

250 kW hydroelectric, and a 250 kW gas generator, implementing a storage with an ultra-condenser (Bayindir et al., 2015).

Table 2 shows Mexico, where the Wal-Mart chain installed 1056 panels in Aguascalientes on the roof of Bodega Aurrerá. This system has 174 kW of installed power and generates 20% of the energy required by the store during a year (Becerra, 2011). The Universidad Autónoma Metropolitana (UAM) inaugurated the Laboratory of Photovoltaic Energy, considered one of the largest in the solar field of Mexico. This installation is connected to the electrical grid of the headquarters located in Iztapalapa, made up by 60 kW of power (León-Trigo et al., 2019). The Photovoltaic Solar Park "Bicentenario" is another successful photovoltaic system installed in Mexico, with an installed capacity of 1 MW (Becerra, 2011, González, 2012). At the level of hybrid microgrids, in X-Calac, there is the implementation of photovoltaic technology with 11.2 kW of power, and 60 kW of wind power, in addition to the integration of diesel generation. At Villas Carrousel, we find the installation of 15 hybrid systems (Wind-Photovoltaic), with 500 W wind power and a range of 150-20 W for photovoltaic, in addition to the provision of a battery bank, operating since 1995. The microgrid in Isla Margarita, implemented with 2.3 kW photovoltaic, 15 kW wind power and a diesel generation of 60 kW, in operation since 1997. The microgrid in San Juanico, has photovoltaic power of 17 kW, 70 kW wind power and one Diesel generator of 80 kW, which began operating in 1999.

Haiti, presented in Table 2, with the EarthSpark International/ZeroBase microgrid, which consists of a hybrid solar-diesel system. It provides its services to residential and commercial customers, as well as to an agricultural processing facility, in the city of Les Anglais. It has a capacity of 90 kW of solar panels, a battery storage system and an emergency generator (Arcamone, 2015).

In Nicaragua, as can be seen in Table 2, it is highlighted the implementation of Small Hydroelectric Power Plants (HPP), among which the Ministry of Environment and Natural Resources (Cantarero, 2018) details the following projects: located on the Coco river, Coco Torres (19 MW), Correa Lira (94 MW), Kamana (114 MW), Pintada (203 MW), Portalupi (55 MW); Located on the Bocay River, Kayaska (54 MW); In Jinotega, Wiwilí (1.3 MW); On the Y-Y River, named Y-Y (27 MW) and on the Tuma River, Zopilota (18 MW).

In the case of a country like Argentina, as presented in Table 2, there is a hybrid system in the Community of Colorado, Jujuy Province, with photovoltaic and diesel generation that operates 3 h/day (Sarmiento et al., 2019).

The Huatacando microgrid in Chile, as observed in Table 3, consists of two photovoltaic systems for a total power of 25 kW, a wind turbine of 5 kW and a diesel generator of 120 kW, while the storage system has a lead-acid battery bank. Its loads are a water supply to houses and residences in the surrounding area (Mata et al., 2013).

In Brazil, there is also a hybrid system installed in Ilha dos Lençóis (municipality of Cururupu), as shown on Table 3, that uses photovoltaic technologies with a total power of 21 kW, 22.5 kW total wind power and one Diesel generator of 42.4 kW, these feed a battery bank, used for energy storage (Guilherme and Morante, 2012); The Xapuri project in the Chico Mendes Reserve, has photovoltaic modules of 80 W each, using a battery storage system (de Sousa Mascarenhas, 2018). While in the municipality of Nova Mamoré, in the State of Rondônia, there is a photovoltaic installation with an installed power of 20.48 kW. However, research and pilot projects are carried out in the country, such as the one carried out by the University of Sao Paulo (USP) with the design of Domestic Photovoltaic Systems, with the installation of photovoltaic systems in the Mamiruá Sustainable Development Reserve, San Francisco de Aiucá, Amazonas, with a production of 13 kWh. For wind energy in Brazil, there are two wind farms, Sangradouro and Los Índios for a total power of 50 MW per park (Chilán et al., 2018).

In Colombia, there are four microgrids based on photovoltaic generation and battery storage systems mentioned by Arcamone, 2015, all these listed on Table 3, are products of the union of two companies Gensa and Hemeva: San Francisco-Triganá (126 kW), Chugandí (21 kW), Caletas (21 kW) and Aguas Blancas (15 kW); all with photovoltaic generation and battery-based storage, to meet the demand of the residential sector around the facilities.

However, Gaona et al., 2015 affirm that the most successful cases of microgrids in non-interconnected Zones are found in Chocó (Titumate) and Guajira (El Cardon). The microgrid Titumate is based on renewable sources by 70% and a 30% is based on diesel. Meanwhile in Guajira, the microgrid found in Cardon is based on wind-photovoltaic generation since the departure of Puerto Bolívar (Cabo de la Vela) and Meera (El Cardon) through a circuit of 13.2 kV.

The district of Nazareth, located in the department of Guajira, has a microgrid with a capacity of 425 kW installed in 2010, based on sources of photovoltaic, wind and diesel generation. Likewise in Cerro la Teta and Flor del Paraíso with photovoltaic and wind generation. In the department of Antioquia, on the other hand, the generation occurs with small hydroelectric power plants, in the case of El Salado and La Encarnación with 1875 kW and 55 kW of power respectively. These micro-hydroelectric plants are also used in the microgrid in Bahía Solano, Chocó (2780 kW). In Isla Fuerte, Bolívar, with photovoltaic generation and diesel generator help, they reach a capacity of 545 kW, using this generation system also in Guainía, Pueblo Nuevo (4.32 KW), Barrancominas (36 kW) and Chorrera, Amazonas (3.6 kW) (Gaona et al., 2015).

3. RESULTS AND ANALYSIS

After the review of demonstrations of the integration of renewable energies into microgrids at an international level, we make an analysis on the state of the art technologies used in generation and storage systems. First, addressing microgrids in Europe, the most exploited generation system is photovoltaic, only in the United Kingdom, University of Manchester. In Ireland, Nimbus, based on wind and cogeneration, does not make use of this generation system. However, some of these microgrids use a wind power

Table 3: Microgrid demonstrations in America, Part II

Name/Country	PV	Solar Thermal	Wind	Fuel Cell	CHP	CCHP	Hydro	Diesel (D)/Steam (S)/ Gas (G)/Biomass (BM)/Biogas (BG)	Driven motor generator	Battery (B) Flywheel (FW) Ultracapacitor (C)	Commercial (C) Industrial (I) Residential (R)	Motor	Static
Huatacondo/Chile	×	-	×	-	-	-	-	D	-	B	R	-	-
Ilha dos Lençóis/Brazil	×	-	×	-	-	-	-	D	-	B	R	-	-
Xapuri/Brazil	×	-	-	-	-	-	-	-	-	B	R	-	-
Nova Mamoré/Brazil	×	-	-	-	-	-	-	-	-	-	R	-	-
San Francisco/Colombia	×	-	-	-	-	-	-	-	-	B	R	-	-
Chugandí/Colombia	×	-	-	-	-	-	-	-	-	B	R	-	-
Caletas/Colombia	×	-	-	-	-	-	-	-	-	B	R	-	-
Aguas Blancas/Colombia	×	-	-	-	-	-	-	-	-	B	R	-	-
Titumate/Colombia	×	-	-	-	-	-	-	D	-	-	R	-	-
El Cardón/Colombia	×	-	×	-	-	-	-	-	-	-	R	-	-
Nazareth/Colombia	×	-	×	-	-	-	-	D	-	-	R	-	-
Cerra la Teta/Colombia	×	-	×	-	-	-	-	-	-	-	R	-	-
Flor del Paraíso/Colombia	×	-	×	-	-	-	-	-	-	-	R	-	-
El Salado/Colombia	-	-	-	-	-	-	×	-	-	-	R	-	-
Encarnación/Colombia	-	-	-	-	-	-	×	-	-	-	R	-	-
Bahía Solano/Colombia	-	-	-	-	-	-	×	-	-	-	R	-	-
Isla Fuerte/Colombia	×	-	-	-	-	-	-	D	-	-	R	-	-
Pueblo Nuevo/Colombia	×	-	-	-	-	-	-	D	-	-	R	-	-
Barrancominas/Colombia	×	-	-	-	-	-	-	D	-	-	R	-	-
La Chorrera/Colombia	×	-	-	-	-	-	-	D	-	-	R	-	-

PV: Photovoltaic, CHP: Cogeneration, CCHP: Trigeneration

generation system as a backup or as a primary source. In this vein, sources of backup generation are used, such as engines powered by generators, as in the University of Manchester, and generation with diesel, steam or gas, cogeneration and trigeneration as is the case of SmartCity Malaga. The most commonly used storage system in Europe is the battery, although some microgrids do not use any storage system, that is, they immediately consume what they generate, in other cases they also use flywheels like Labein microgrid in Spain, CESI in Italy and the University of Manchester. Only in the case of Labein are ultracapacitors used. Generally, the loads fed in Europe are Residential, with few commercial and industrial loads as is the case of Spain in Labein and SmartCity Malaga.

Meanwhile, Asia, presented on Table 1 with Japan as one of the countries with more microgrids implemented. Their most used generation sources are solar, and as backup sources, wind, fuel cells and generation with diesel, steam or gas. In the American continent, the situation is a bit different with respect to the sources of generation, because they apply microgrids with the intention of improving the quality of the energy, therefore, they prefer sources that are more continuous over time, or the combination of sources; solar, wind, fuel cells with gas, steam and/or diesel generators with a wide application of batteries as a storage system. In the United States there is a good amount of microgrids, among which it is observed a predominance of photovoltaic generation and the use in smaller quantity, but not less important, of wind energy, backed up with vapor or diesel generation. In addition this shows the use of batteries as the main storage system. In other countries, the trend is towards large implementations of wind and solar photovoltaic technology for the supply of residential type loads. The large implementation of small hydropower plants in countries like Colombia and Nicaragua with many such projects is noteworthy.

4. CONCLUSION

A detail review of practical implementation of Microgrids deployed around the world has been carried out, classifying them according to the revision schemes proposed in the document. From this review of microgrid experiences in general, it is emphasized: The loads that take advantage of generation with microgrids are usually residential or commercial, and only a few extend to industrial types, as in the case of Smartcity Malaga and Labein in Spain, and in Japan with several of its microgrids. The implementation of systems of solar, wind and diesel generation with steam or gas are the most used technologies for the generation of energy.

The most widely used storage system is batteries, with the purpose of providing electricity during non-solar hours, and the inclusion of Flywheels in countries such as Spain and Italy, in the Labein and CESI microgrids respectively. Also, the great technological advancement to develop batteries with greater load capacity while maintaining a small size or with better performance, electrically speaking, continues being a determining factor for them to remain most important in storage technology, displacing super-capacitors.

REFERENCES

Amin, M. (2016), Hybrid Microgrid and its Coordination, Doctoral Dissertation, California State University, Northridge.

Arango, A., Álvarez, R. (2013), Microgrids: New paradigm in electricity grids. Revista Colombiana de Tecnologías de Avanzada, 2(22), 42-48.

Arcamone, R. (2015), Battery selection for different microgrids. In: 2015 Trojan Battery Company, Munich, Germany. p1-20.

Bayindir, R., Bekiroglu, E., Hossain, E., Kabalci, E. (2014), Microgrid facility at European union. In: 2014 International Conference on Renewable Energy Research and Application. United States: IEEE. p865-872.

Bayindir, R., Hossain, E., Kabalci, E., Billah, K.M.M. (2015), Investigation on North American microgrid facility. International Journal of Renewable Energy Research, 5(2), 558-574.

Becerra, H. (2011), Desarrollo y aplicaciones de microrredes eléctricas en México. In: Taller Sobre Minirredes y Sistemas Híbridos con Energías Renovables en la Electrificación Rural-Universidad de Sao Paulo. p1-65.

Bordons, C., Torres, F.G., Valverde, L. (2015), Gestión óptima de la energía en microrredes con generación renovable. Revista Iberoamericana de Automática e Informática industrial, 12(2), 117-132.

Cabello-Eras, J., Balbis-Morejón, M., Sagastume-Gutiérrez, A., García, A.P., Ulloa, M.C., Rey-Martínez, F.J., Rueda-Bayona, J.G. (2019), A look to the electricity generation from non-conventional renewable energy sources in Colombia. International Journal of Energy Economics and Policy, 9(1), 15-25.

Cantarero, M.M.V. (2018), Reviewing the Nicaraguan transition to a renewable energy system: Why is “business-as-usual” no longer an option? Energy Policy, 120, 580-592.

Chilán, J.C.H., Torres, S.G.P., Machuca, B.I.F., Cordova, A.J.T., Pérez, C.A.M., Gamez, M.R. (2018), Social impact of renewable energy sources in the province of Loja. International Journal of Physical Sciences and Engineering, 2(1), 13-25.

de Sousa Mascarenhas, F., Brown, I.F., da Silva, S.S. (2018), Desmatamento e incêndios florestais transformando a realidade da Reserva Extrativista Chico Mendes. Desenvolvimento e Meio Ambiente, 48, 236-262.

Falahati, B., Chua, E., Kazemi, A. (2016), A novel design for an expandable, modular microgrid unit. In: 2016 IEEE Power and Energy Society Innovative Smart Grid Technologies Conference. United States: IEEE. p1-5.

Gaona, E.E., Trujillo, C.A., Guacaneme, J.A. (2015), Rural microgrids and its potential application in Colombia. Renewable and Sustainable Energy Reviews, 51, 125-137.

González, H.D. (2012), Diseño De Un Sistema Fotovoltaico Para La Generación De Energía Eléctrica En El Cobaev 35 Xalapa. p1-172. Available from: http://www.cdigital.uv.mx/bitstream/123456789/31561/1/dominguezgonzalezhector.pdf. [Last accessed on 2019 Dec 01].

Grids, S. (2011), La Evolución de la Red Eléctrica, Observatorio Industrial del Sector de la Electrónica, Tecnologías de la Información y Telecomunicaciones.

Gui, E.M., Diesendorf, M., MacGill, I. (2017), Distributed energy infrastructure paradigm: Community microgrids in a new institutional economics context. Renewable and Sustainable Energy Reviews, 72, 1355-1365.

Guilherme, P., Morante, F. (2012), A busca pelo sucesso em projetos de eletrificação rural descentralizada por meio de sistemas híbridos de geração de energia elétrica. In: VI Encontro Nacional da Anppas, Belém. p1-28.

Hatziargyriou, N. (2014), Microgrids: Architectures and Control. United States: John Wiley & Sons.

Jiang, L., Wang, C., Huang, Y., Pei, Z., Xin, S., Wang, W., Brown, T. (2015), Growth in wind and sun: Integrating variable generation in China. IEEE Power and Energy Magazine, 13(6), 40-49.

Josa, A.C. (2011), Primeros pasos hacia las redes inteligentes en España. Visión del operador del sistema. Cuadernos de Energía, 32, 33-41.

Lee, Y.D., Chang, Y.R., Chan, C.M., Ho, Y.H. (2012), Preliminary implementation of microgrid with photovoltaic and microturbine for stand alone operation. In: 2012 IEEE Industry Applications Society Annual Meeting. United States: IEEE. p1-9.

León-Trigo, L.I., Reyes-Archundia, E., Gutiérrez-Gnecchi, J.A., Méndez-Patiño, A., Chávez-Campos, G.M. (2019), Smart grids en México: Situación actual, retos y propuesta de implementación. Ingeniería, Investigación y Tecnología, 20(2), 1-12.

Lidula, N.W.A., Rajapakse, A.D. (2011), Microgrids research: A review of experimental microgrids and test systems. Renewable and Sustainable Energy Reviews, 15(1), 186-202.

Mahieux, C., Oudalov, A. (2014), Microrredes: Integración de microrredes con tecnologías de ABB. Revista ABB, 4, 54-60.

Mata, O.N., Villalba, D.O., Palma-Behnke, R. (2013), Microrredes en la red eléctrica del futuro-caso Huatacondo. Revista de Ciencia y Tecnología, 29(2), 1-16.

Morozumi, S. (2015), Japanese island grid experience. In: Island Energy-Status and Perspectives. Available from: https://www.iea.blob.core.windows.net/assets/imports/events/111/3morozumi_nedo.pdf. [Last accessed on 2020 Mar 01].

Munoz, A. (2019), Microgrids for disaster management: An ethical risk perspective. IEEE Technology and Society Magazine, 38(4), 70-74.

Muñoz, Y., Zafra, D., Acevedo, V., Ospino, A. (2014), Analysis of energy production with different photovoltaic technologies in the Colombian geography. IOP Conference Series: Materials Science and Engineering, 59(1), 012012.

Nam, Y.H., Lee, H.D., Kim, Y.R., Marito, F., Kim, M.Y., Rho, D.S. (2017), Economic evaluation algorithm of island micro-grid for utility and independent power producer. The Transactions of the Korean Institute of Electrical Engineers, 66(7), 1032-1038.

Onodera, O. (2013), Micro-grid activities related to Japan. In: Microgrid World Forum, Irvine, California, Estados Unidos. p1-24.

Ospino, A.J.C., Ortega, J. (2013), Set of elements, parameters and considerations to get the successful inclusion of the smart grids in Colombian power systems. In: IMETI 2013-6th International Multi-Conference on Engineering and Technological Innovation. p166-169.

Papaioannou, D.I., Papadimitriou, C.N., Dimeas, A.L., Zountouridou, E.I., Kiokes, G.C., Hatziargyriou, N.D. (2014), Optimization and sensitivity analysis of microgrids using HOMER software-a case study. In: India Conference (INDICON). United States: IEEE.

Rese, L. (2012), Modelagem, Análise de Estabilidade e Controle de Microrredes de Energia Elétrica, Doctoral Dissertation.

Rueda-Bayona, J.G., Guzmán, A., Eras, J.J.C., Silva-Casarín, R., Bastidas-Arteaga, E., Horrillo-Caraballo, J. (2019), Renewables energies in Colombia and the opportunity for the offshore wind technology. Journal of Cleaner Production, 220, 529-543.

Sarmiento, N., Belmonte, S., Dellicompagni, P., Franco, J., Escalante, K., Sarmiento, J. (2019), A solar irradiation GIS as decision support tool for the Province of Salta, Argentina. Renewable Energy, 132, 68-80.

Shuai, Z., Sun, Y., Shen, Z.J., Tian, W., Tu, C., Li, Y., Yin, X. (2016), Microgrid stability: Classification and a review. Renewable and Sustainable Energy Reviews, 58, 167-179.

Sood, V.K., Abdelgawad, H. (2019), Microgrids architectures. In: Distributed Energy Resources in Microgrids. 10th ed. Cambridge: Academic Press. p1-31.

Tamaki, M., Uehara, S., Takagi, K., Ichikawa, T. (2012), Demonstration results using Miyako island mega-solar demonstration research facility. In: PES T&D 2012. United States: IEEE. p1-4.

Tobin, P., Schmidt, N.M., Tosun, J., Burns, C. (2018), Mapping states' Paris climate pledges: Analyzing targets and groups at COP 21. Global Environmental Change, 48, 11-21.

Tolón, T.I.M. (2013), Operación y Gestión de Microrredes Energéticas Urbanas en un Entorno de Sostenibilidad Energética y Ambiental (Master's Thesis, Universitat Politècnica de Catalunya). Available from: http://www.upcommons.upc.edu/pfc/bitstream/2099.1/19411/1/tamaratolon_memoriatfm_deposito.pdf. [Last accessed on 2020 Feb 10].

Xie, H., Zheng, S., Ni, M. (2017), Microgrid development in China: A method for renewable energy and energy storage capacity configuration in a megawatt-level isolated microgrid. IEEE Electrification Magazine, 5(2), 28-35.