Investigation on North American Microgrid Facility

Ramazan Bayindir*‡, Eklas Hossain**, Ersan Kabalci***, Kazi Md Masum Billah****

*Gazi University, Faculty of Engineering, Department of Electrical & Electronics Engineering, 06500, Ankara-Turkey

**Department of Mechanical Engineering, University of Wisconsin Milwaukee, Milwaukee, WI-53211, USA

***Nevsehir University, Faculty of Engineering, Department of Electrical & Electronics Engineering, Nevsehir-Turkey

****World University of Bangladesh, Faculty of Engineering, Department of Textile Engineering, Dhanmondi Dhaka, Bangladesh

(bayindir@gazi.edu.tr, shossain@uwm.edu, kabalci@nevsehir.edu.tr, masum.me106@gmail.com)

‡ Corresponding Author; Ramazan Bayindir , Gazi University, Faculty of Engineering, Department of Electrical & Electronics Engineering, 06500, Ankara-Turkey , bayindir@gazi.edu.tr

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Abstract- According to international reports that have also cited in this article, North America covers the 66% of the global electricity that has generated in microgrids. Besides its 2088 MW installed microgrid capacity in 2012, many new microgrids have been installed in North America. The microgrid plants under development, new planned, and proposed will pursue the leading rank of North America all over the world. Therefore, it has intended to analyze the microgrid plants and studies performed in this region to disseminate the findings. This paper presents a review of various North American distributed generation plants together with their tabled test-beds. The microgrid (MG) projects introduced in this study are surveyed according to their generator structures, their integration to the point of common coupling (PCC), and operation structures. The uniqueness of each MG project has shown in comparison to several others. In addition, the emergency and crisis management methods, precautions against overcharge and low generation issues are also introduced for each MG plant. This allows the researcher to visualize today's microgrid and to gain insight into the possible evolvement of future grids. The study concludes by emphasizing significant findings and by suggesting potential research areas that would enhance microgrid facilities.

Keywords- Microgrid facility; distributed generation technology; microgrid test-bed; renewable resource.

1. Introduction

It is easy to understand why companies and electric utilities are interested in microgrids when the expanding nature of the utility transmission and distribution (T&D) system has investigated. The American Council of Civil Engineers rated the US system a modest D+ in 2009 taking into consideration both recent developments and relating initiatives in new era sources. Lawrence Berkeley National Laboratory (LBNL) indicates that 80% to 90% of all network interruptions start at the dispersion level of power administration. Microgrid (MG) advocates, both within and outside the military, contend that these frustrations can moderate at the nearby appropriation level through microgrid innovations. In Fig.1, we indicate the center of the onsite generation landscape. As can be seen from figure, most of the R&D improvements came from the DOE/DOD and ARRA SGDP; while the industry leads facility centers are located in California, Illinois, and Washington DC. Since power practically moves at the speed of light, or 186,000 miles per second, a power interrupt of milliseconds can crash basic radar systems or disturb vital life support systems in Veterans Administration (VA) clinics. On average, every US customer endures a four-hour power outage annually, a blackout rate 30 times higher than in Japan [1]. The most important characteristic of a microgrid is islanding, or the ability to differentiate and separate itself from the utility appropriation system throughout brownouts or power outages. This creates the capacity to improve oversight of the distribution of renewable resources such as sun based photovoltaic arrays or wind. This is why the US Department of Defense (DOD) is so captivated by microgrids since these islanded structures can disengage basic mission capacities from the larger lattice, guaranteeing secure power under an assortment of desperate situations, including terrorist attacks and other types of threatening intercessions [1].

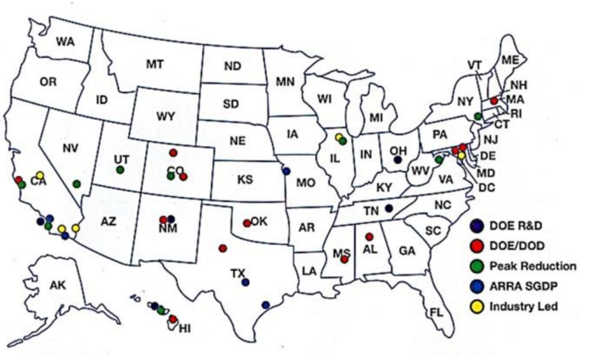

Fig.1. Present microgrid facility scene in US [1, 47].

In recent years, there has been a huge increase in the deployment of microgrids at national, institutional and private levels. The number of effectively installed microgrids will improve the profits and lower interruption threats, thus further enlarging the commercial market for microgrids. As shown in Fig.2 [2], the annual business loss from grid problems such as power outages and quality concerns is $150B [2]. Although most of the losses are between $0.2B and $4B, California suffers the highest loss with an annual $18.5B.

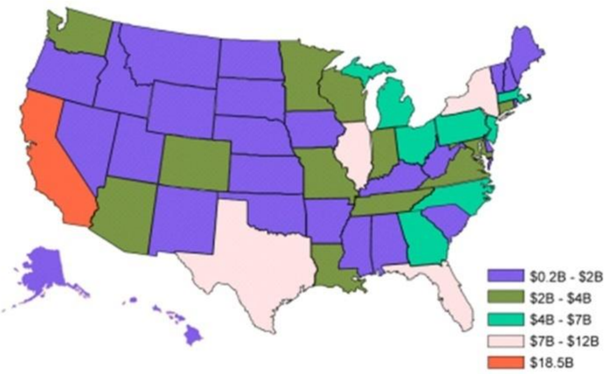

Fig.2. Annual business losses from grid problems in US [2].

While green innovation academics might not be considering Stamford's microgrid plant, the business arena is certainly interested. In recent times, discriminating business and fiscal centers have developed in many Connecticut cities including Stamford, with a population of more than 100,000. In addition, the Royal Bank of Scotland moved its US headquarters to Stamford in 2009. UBS, the Swiss global financial services company, has a branch in Stamford as do many other organizations including International Paper, GE Capital and Xerox. The deployment of microgrid applications in various industries in the next five years has illustrated in Fig. 3, from which it can see that the highest rates are in the healthcare, military, government, and manufacturing sectors. The residential, agricultural, and educational sectors are also increasing their share of microgrid applications, which is currently 30% and growing [3].

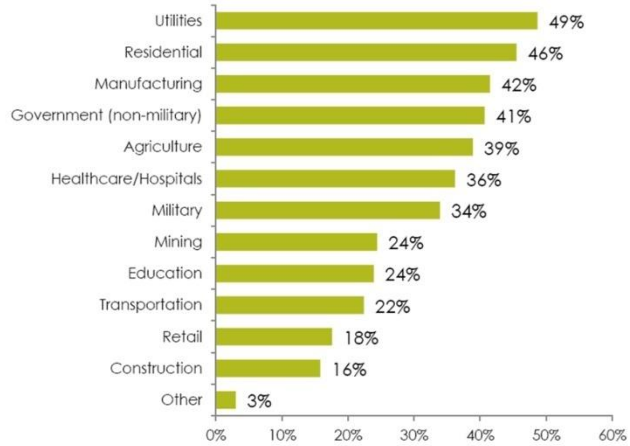

Fig.3. The deployment of microgrid application in various industries in next 5 years [3].

United Technologies Connecticut chose to run a solar and fuel cell power module based microgrid. They truly needed to make their building require zero consumption of energy from the utility grid because of emergency power concerns, physical and cyber security issues and the possibility of natural disasters such as storms. While these projects are still at the research and development (R&D) stage, in the near future buildings will be able to draw power from their built-in generation systems during power outages. In Fig. 3, we show the commercial plants that are well on their way to completing microgrids in the following five years [3].

The power generation structure, integration rate and the number of PCCs of a microgrid affect the coupling between the MG and the utility grid. Although most MG plants have just one PCC to utility grid, the large-scale MGs require multiple PCCs that must be arranged correctly way. Thus, the control and prevention methods become more complex as the system faces lightning strikes, power failures and other damage in common with the utility grid. These drawbacks have expected to tackle by the inbuilt protection methods of the MG. In order to prevent the MG from high voltage and frequency oscillations, planned islanding should consider performing the disturbance rejection feature. Planned islanding is one of the most important challenges to improve the structure of the MG itself. Therefore, transient damage can easily be tackled and load demands are met in a sustainable way [4,5].

The US Department of Defense promotes MG research alongside scientific research in North America. This relates mostly to the DOD's heavy dependence on fossil fuels on almost all its military bases. In addition, according to the DOD, the biggest challenge on the battlefield is electricity generation. From this point of view, the DOD considers that MG can decrease fossil fuel requirements [6]. Thus, the DOD is one of the major proponents of MG research and installations in North America for their own tactical support. LBNL reports that 90% of outages in North America have caused by distribution system deficiencies [7]. Thus, the main motivation behind increases in MG installation and research is to decrease the billions of dollars lost during outages [7,8]. In order to achieve this goal, the US DOE under the Office of Electricity Delivery and Energy Reliability (OE) has re-scheduled the R&D of the next generation of MGs as high priority in order to accomplish the vision of developing commercial scale MGs before 2020. The commercial scale MGs have expected to be lower than 10 MW capacities but capable of reducing outage times by up to 98%. This vision also foresees the reduction level of emissions to be around 20% while the energy efficiency is over 20% [8].

Regarding to these surveys, it is obviously seen that the MG plays a vital role in several sectors such as healthcare, transportation, military, and governmental. On the other hand, North America that is the leader region in MG should be clearly analyzed to define improvements seen on MGs. This research consists of a survey of MG test-beds installed in North America in order to analyze the level of interest and research focused on MG. It also aims to present MG structures and approaches to describe recent advances in distributed generation issues. The MG test-beds are classified according to their geographical locations in Canada in the 2nd section, Northern USA in the 3rd section, Southern USA in the 4th section, Western USA in the 5th section, and Eastern USA in the 6th section. Each test-bed is selected and introduced according to its technical infrastructure, generator and storage systems, emergency management methods, communication, and load management features. The aim is to present a comprehensive survey of MG test-beds installed in North America. For this purpose, several tabulated data containing the detailed properties of test-beds have given in the seventh section in addition to schematic diagrams of test-beds.

2. Microgrid Testbed in Canada

2.1. Boston Bar – British Columbia (BC) Hydro, Canada

The objective of this project is to provide improved reliability and security on rural feeders with fast response times in British Columbia, by using a located autonomous power producer (APP). The microgrid of three radial feeders (BC hydro distributed system) has interconnected to 69 kV feeders by a 69/25 kV substation. This structure strengthens the power throughout great climatic changes. When the high voltage feeder confronts any deficiency, it can work in island mode. Fig.4 exhibits the online diagram of the T&D system of the Boston Bar Hydro system of 69/25 kV substation. The microgrid embodies two 4.32 MVA hydropower generators joined by a single power bus. It gives power to the load after synchronization [9]. The schematic diagram of the T&D system of Boston Bar Hydro system is depicted in Fig.4 where the BC hydro-line to the Boston Bar connection is shown over 14MVA transformer substation. The power factors of generators, feeders, and breakers have illustrated in the figure [9].

There is no storage system in the BC bar hydro plant, but the inertia of the generators has enlarged intentionally. Additionally, they used a payable phone line for communication. The arranged islanding practice has been working since 1995.

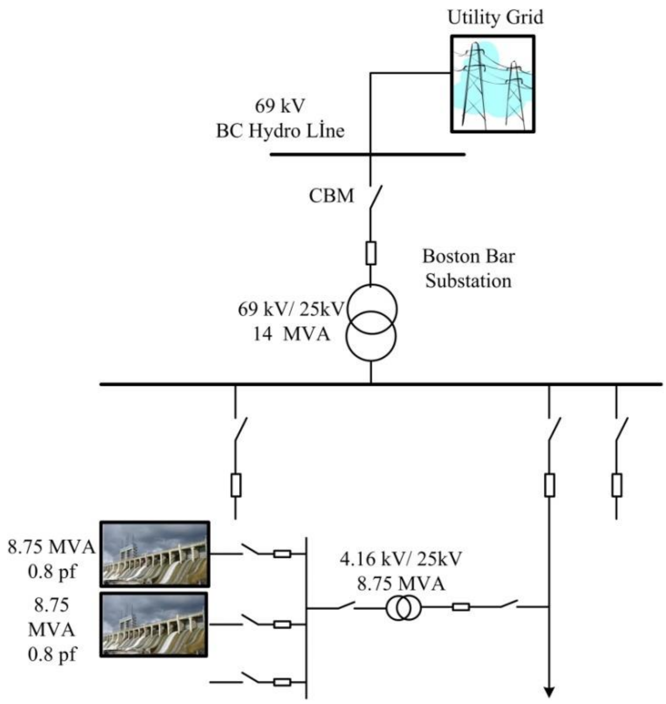

Fig.4. The online diagram of transmission & distribution system of Boston Bar Hydro system [10]

Moreover, the hydro microgrid has the capacity to include substation level or island mode immediately so utilizing remote auto-synchronization without bringing on load shedding. This proving ground and genuine system operation has automatic and manual synchronization; and tested with step load and dead load with black-start competence utilizing a 50-kw diesel generator [10-12].

2.2. Boralex planned islanding plant at Senneterre Substation – Hydro Quebec (HQ), Canada

The objective of the Hydro Quebec planned islanding is to back up a 55-year-old transmission line, which has managed by Boralex (thermal power plants). The Senneterre substation in Quebec supplies three circulation lines that serve 3,000 clients. The substation, with wood stand, supplies at 120 kV via a 40 km transmission line, which was in need of substantial repair. The hydro generator demonstrates stable operation in isochronous mode under differing loads where the peak load tried was about 7 MW. The arrangement of the islanded Boralex plant at the Senneterre Substation has illustrated in Fig.5 [13-17]. The transmission line and feeder connections to substations are clearly depicted with their breaker connections.

The primary equipment incorporates assurance of quality, solidness investigation of island mode for frosty load pickup and start-up of engine loads according to high present blames; and level and different sorts of glint study. HQ Senneterre system did several tests for eight hours in October 2005 where the execution was successful in terms of security and the crest load was 7 MW. Later, to build a reliable power system, they utilized disengagement and reconnection of one dispersion feeder at once, and the detachment of all conveyance feeders.

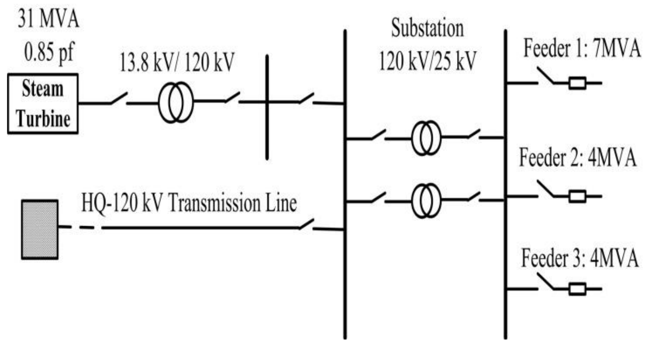

Fig.5. Boralex planned islanding plant at Senneterre Substation [13].

Finally, trial and reproduction outcomes demonstrated that voltage and recurrence remained stable for both the load reduction test and the regulated load test. Consequently, the fundamental motivation behind this HQ mission was to support the transmission line, and work with a single, comparatively large generator unit. It did not require any space or correspondence system [15-17].

2.3. Converter fed microgrid at Toronto

The converter fed microgrid test-bed comprises capacitors, with loads both static and motor, which connect through utility by a power bus bar as shown in Fig.6.

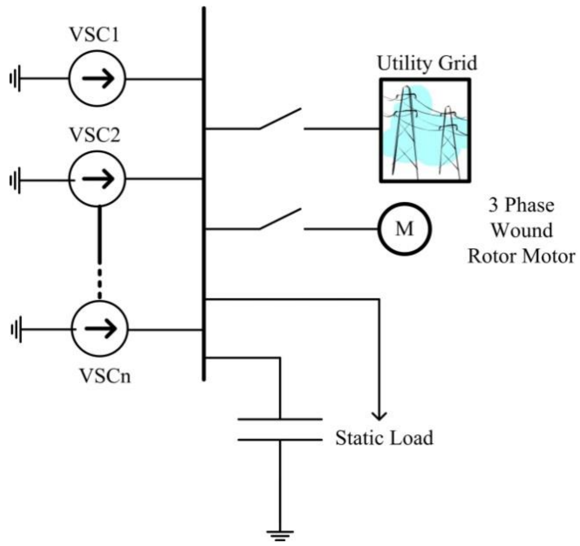

Fig.6. A microgrid with multiple VSCs [18].

In this experiment, researchers ignored line impedance, as it is usually short enough and a balanced load. At the point of common coupling (PCC), the microgrid interconnects with the utility through a circuit breaker. The high bandwidth current controller used here intends to interface various power sources. The voltage power or frequency reactive power control method has used in this test facility to operate both islanded and grid-tied mode based on demand. The multiple voltage source converters (VSC) use to control both the voltage and frequency of the microgrid at islanded mode while the utility grid helps to maintain power quality during grid-tied mode. Radial distribution system has been used in this plant to interconnect sources and loads [15,16-20].

2.4. Ramea wind-diesel microgrid at Newfoundland and Labrador

The wind-diesel Ramea microgrid at the Newfoundland and Labrador site that was installed in 2004 is selected since it is based on a few key points such as significant isolated communities, intensely interested community support, adequate wind resource (7.5 m/s), and an isolated yet accessible, non-Arctic environment. The configuration of Ramea wind-diesel microgrid in Canada has shown in Fig. 7. The selection of this remote distribution structure was to demonstrate a real Canadian utility with confined neighborhoods and impact around utilities, and showing innovative viewpoints and efficient angles. This generator is chiefly devoted to a small island 10 km from the south shore of Newfoundland with a population of 700 (conventional fishery neighborhood). It is a self-ruling diesel-based system with medium scale wind plant [21]. The system has a peak demand of 1.2 MW, and the joined wind establishment has appraised at 395 kW. If the power generation of diesel plant decreases down to 30% of its capacity, then the control mechanism recover the lost potential by integrating wind turbines to the system until the diesel generator again supplies over than 30% of its capacity. The average load of the planned system is 528 kW while the least load is 202 kW against twelve-month energy generation of 4,556 MWh, two dissemination feeders (4.16 kV), diesel plant (3-925 kW diesels of CAT 3512 – 1200 RPM), woodward controls, and modicon PLC [22-24].

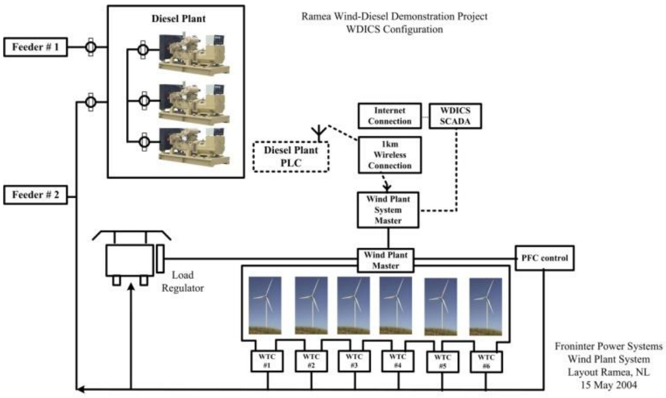

Fig.7. The configuration of Ramea wind-diesel microgrid in Canada [31]

The interesting characteristics of the Ramea that helped to extend microgrid R&D are [25]:

- Analysis of discontinuous nature effects of wind power on recurrence and voltage control in a self-sufficient system,
- Investigation of correspondence and SCADA in the operation of a completely robotized wind-diesel system, specifically for energy administration and unsteadiness issues,
- Investigation and control of power quality issues.

2.5. *Fortis-Alberta microgrid at Alberta*

The 7 MW utility Fortis-Alberta transmission structure shown in Fig. 8 was installed around 2006 and is recognized as an arrangement tied microgrid. The system holds a 25-kV conveyance system supplied from a 25-kV/69-kV substation ordinarily joined to the substation through PCC. In purposeful island mode throughout substation support periods or consequent to interruptions, the power supply has typically kept up by briefly associating the circulation system to the 25-kV conveyance feeder, checked temp-feeder, supplied by a 25-kV/69-kV substation. An elective technique to supply the heap is to constitute a contingent island upon satisfactory accessibility of power from neighborhood DERs. On the other hand, moderate reaction of the hydro unit and the irregular nature of the wind turbines force limitations that allow just arranged islanding. Additionally, the discontinuous nature hotspots such as wind-dependence of wind rate and hydro-water level reliance create challenges for load succeeding while islanded. Joining of quick acting, dispatchable DERs is an option to overcome these islanding operational issues [26].

The Fortis-Alberta microgrid system embodies 3 MW run stream hydro and 3.78 MW variable-speed wind turbines, which create by the CANMET energy group. Canada's microgrid program sufficiently advances to provide a test-bed for innovative work as well as for modern evaluation model testing and for execution assessment. The Fortis Alberta network tied microgrid system is particularly appropriate for examination.

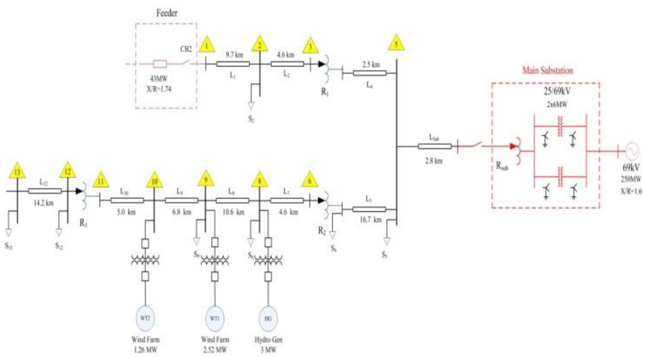

Fig.8. Schematic diagram of Fortis-Alberta microgrid [26].

2.6. *British Columbia Institute of Technology Microgrid test-bed at BC*

The British Columbia Institute of Technology (BCIT) has created a scaled-down form of the microgrid to present to utility organizations and scientists [27]. All parties interested in this subject can cooperate to create related parts of the microgrid, such as the system, conventions, test banks, and other necessary trial setups to support the improvement and to publicize the results of the improvement of microgrid engineering in North America. The 1.2 MW microgrid was created at BCIT's Main Campus in Burnaby around 2009. This yard sort microgrid comprises two wind turbines (5 kW each), PV modules (300 kW), warm turbine (250 kW), Li-particle battery (550 kWh) and ground loads (EV charging stations, mechanical load, classrooms and business settings, homes) [2]. There is an “assemble and control” unit, which is fitted with a substation robotization lab, MG operation control focus and MG controller. A facilities-wide correspondence system was additionally accessible for this conveyance system including WI-Max, ISM RF, PLC, Fiber et cetera as demonstrated in Fig.9 [27].

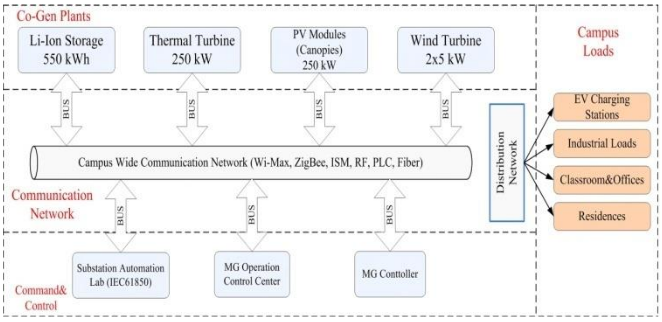

Fig. 9. Block diagram of British Columbia Institute of Technology microgrid [48]

3. Microgrid test-beds in Northern Regions of America

The United States has had a modest but gradually expanding microgrid exploration program for several years, supported both by the U.S. Division of Energy (DOE) under the Office of Electricity Delivery and Energy Reliability (OE), and by the California Energy Commission (CEC) through its Public Interest Energy Research Program [10,26]. Increased interest in high power quality and reliability (PQR) in the USA, principally to match the high end of heterogeneous closure use prerequisites, has characteristically prompted expanded concentration on improving PQR, generally by utilizing microgrids. The existing microgrid test facilities have illustrated below.

3.1. CERTS Microgrid test-bed in Ohio:

The target CERTS microgrid laboratory test-bed undertaking has designed to exhibit three progressed systems embodying the CERTS microgrid on a full-scale proving ground worked by AEP [24]. The main set of tests inspected the operation of the static switch to establish that it and its digital signal processor (DSP) control worked as planned. The second set of tests analyzed a preparatory set of shortcoming condition tests to guarantee the insurance and wellbeing of the proving ground, preceding the performance of other arranged tests. The third set of tests intended to guarantee that the gen-set inverter controls were acting as outlined. The fourth set of tests showed the adaptability of the microgrid both lattice associated and islanded for distinctive loads, force streams and effect on the utility. The fifth and last set of testing investigated the furthest reaches of the microgrid operation (i.e., power quality, insurance and inverter limits) with engine beginning loads [13,18].

The testing completely affirmed prior research that had been conducted through expository reproductions, then through lab imitations, and finally through production line acknowledgement testing of singular microgrid segments. The islanding process and resynchronization strategy satisfied all IEEE 1547 and power quality requirements. The electrical security system was ready to recognize ordinary and blamed operations. The controls have found to be powerful for all circumstances.

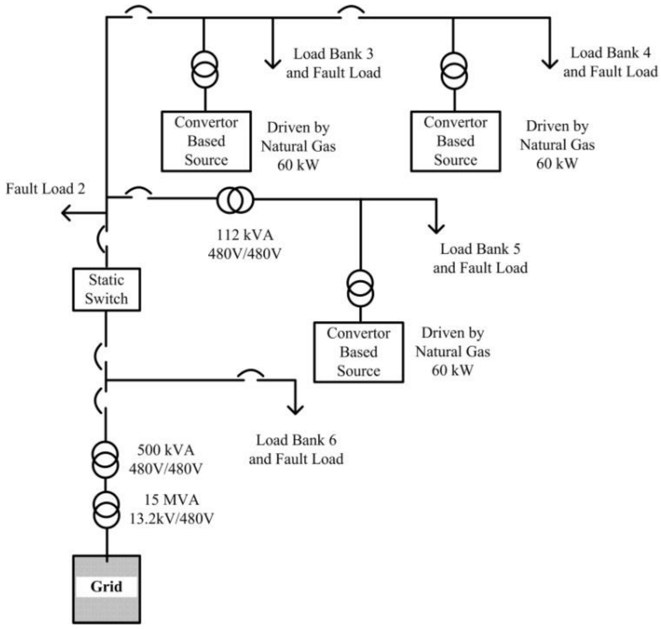

Fig.10. CERTS Microgrid test-bed in Ohio [13]

CERTS was created in 1999 to research, create, and scatter novel systems, instruments, and innovations to secure and improve the unwavering quality of the US electric force system and proficiency of focused power markets [13,18]. CERTS is creating engineering results that help focused markets while ensuring the general population premium in dependable power administration [15]. American Electric Power has installed full-scale onsite generation in Columbus, OH. The facility consists of natural gas generators, converter based source, loads and an energy storage device. This three-feeder system has interconnected with a circuit breaker and has the facility to operate in both islanded and grid-tied modes as shown in Fig.10. A non-dynamic control of the test-bed has established through an ethernet communication system, which helps to achieve plug and play capability autonomously. A peer-to-peer control method has used to regulate the entire independent system [15].

3.2. UW Madison microgrid test-bed in Madison:

The distributed generation test-bed at the University of Wisconsin–Madison demonstrated in Fig.11 has designed to examine display and control matters in joining diesel generators into microgrids that would likewise incorporate converter based sources. It is a spiral sort of microgrid test-bed for yard provision with renewable DG sources (PV) and nonrenewable DG sources (diesel).

Dynamic force recurrence hangs and voltage control has used to control the AC microgrid of CERTS independently. An electric cell utilizes as the energy space component with the converter based system and the Ethernet system is accessible as a correspondence arrangement of offices. A compensation of 3 Hz frequency control has achieved by using a traditional mechanical governor for diesel engines where the voltage controller maintains certain voltage levels. However, frequency controls for converter based source has a drop of 0.5 Hz.

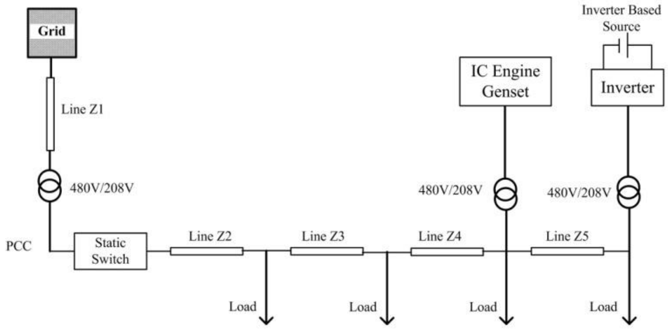

Fig. 11. University of Wisconsin Madison microgrid test-bed [18]

The stable microgrid facility has huge circulating reactive power flows during islanded configuration and data present of exciter machine controls dependent upon the hang of reactive power versus voltage [15,18,19].

3.3. Hawaii Hydrogen Power Park

A mixture (wind/solar/electrolyzer/fuel cell) energy system furnishes discharge free power to Kahua Ranch situated on Hawaii Island, which is part of the huge Island Power Park. The system arrangement has demonstrated in Fig.12. The gear joins with a 48-V DC transport through DC-DC interfaced converters. Control of the gear, controller of supply and interest, and voltage regulation have created where the power supplied to load through an inverter. For the fleeting space, battery bank has utilized while the hydrogen space system gives hydrogen to the fuel cell stack for the long haul space. The hydrogen space is a chamber tank that can store approximately 50 Nm^3 of hydrogen, which changes over to 50-60 kWh of power assuming the FC stack productivity to be 40%. This test-bed can perform different investigations such as, testing execution of stream batteries, ultra capacitors, bio-gas fuel, and so on without any kind of correspondence medium [11,28,29].

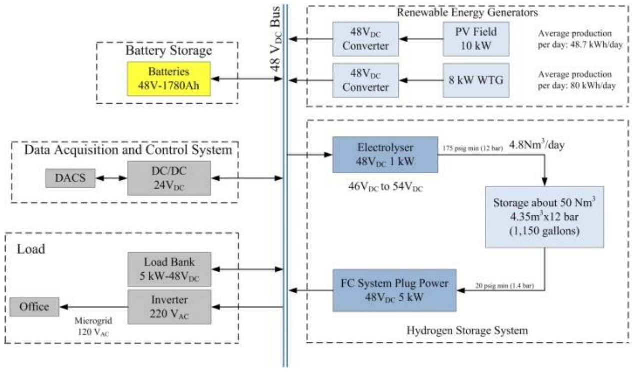

Fig. 12. Schematic diagram of Kahua Ranch Power Park System [11].

4. Microgrid test-beds in Southern Regions of America

4.1. *University of Miami microgrid test-bed*

While most microgrid executions convey energy assets inside a solitary level, here the scientists proposed a methodology utilizing a various leveled scheme to execute the microgrid. The DC interfaced microgrid studies at University of Miami incorporate a PV board, a power device and an electric cell, which coupled to the same DC voltage transport by suitable DC-DC power converters and controls, as shown in Fig.13. This system depends on the premise that homes will have PV exhibits or other power sources, electric storage device reinforcements, and nearby DC power utilization, for example, LED lighting, customer hardware, and so on [30,31].

There is a three-stage pecking order in this skeleton through progressive power hardware and proper controls: DER units are coordinated to a DC transport interface through DC/DC or AC/DC converters; aggregation DC transports then mix into an AC transport connection via inverters; and an extent of AC transports is finally joined into a microgrid. Microgrids could be directly associated with the power circulation system using a point of common coupling (PCC).

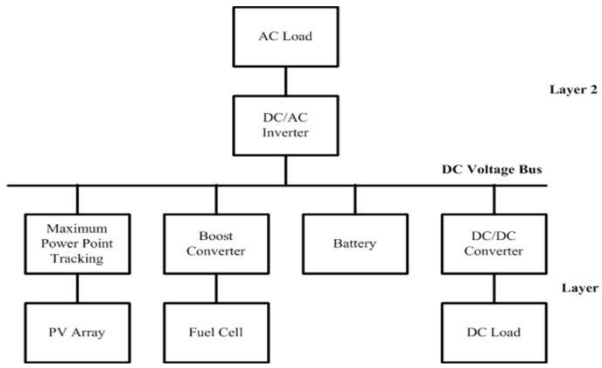

Fig. 13. DC linked microgrid at Florida [40].

DC loads, for instance private loads, might be directly associated with the neighborhood of DC transports, while AC loads are coupled to the AC transports through feeders. The two kinds of controlling strategy widely utilized for the PV subsystem are maximum power point tracking (MPPT) mode and transport (electric storage device) voltage limit (TVL) mode. Furthermore, as the energy component works under relentless state conditions, the electric storage device is answerable for transient changes by supplying or retaining quick crest force. Therefore, the controller is answerable for dealing with the power device yielding current and controlling the transport voltage. A prototype PID compensator connected to a PWM generator has chosen for energy unit current control and it turns off when the electric storage device is completely charged. This chain of command based methodology furnishes more adaptable, unwavering quality for DER joining and empowers an attachment that is achievable without a correspondence system [15, 32].

4.2. *University of Texas at Arlington microgrid test-bed*

The University of Texas at Arlington microgrid lab contains three autonomous delegate microgrids working in system tied or islanded design. Every representative network has a 24 V_{DC} transport and a 120V-60Hz AC transport. For regular setup, two 12 V_{DC} lead harsh corrosive electric cells are coupled in arrangement as the essential energy space. The electric cells on every array are revived utilizing committed sun oriented boards and wind turbines, or a PEM power module and DC/AC inverter made by Outback Power Systems. Programmable load is associated with every AC transport. The network has Crydom strong state transfers mounted on the different transports, which regulates utilizing a National Instruments Compact RIO control system. The whole UTA lattice has demonstrated in Fig.14 [33].

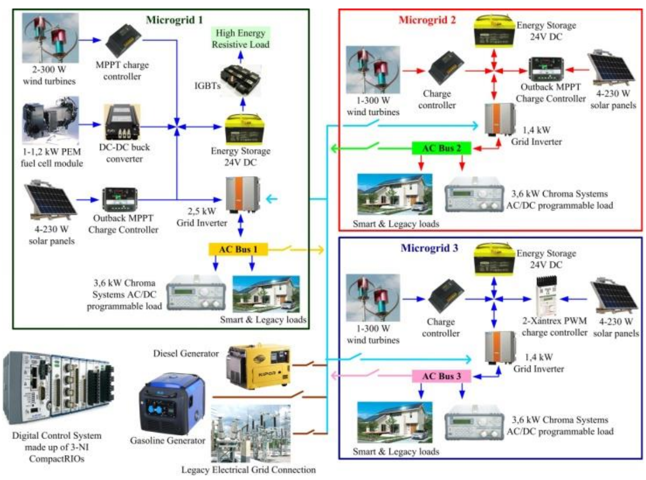

Fig.14. University of Texas at Arlington microgrid laboratory [30].

The execution of a microgrid depends on its capacity to supply dependable and quality power to loads inside the models set out by characterized particulars, for example, MIL-STD-1399- 300b or IEEE-STD-519. In each of these models, regulations has given, which determine the passable difference in the voltage, current, and recurrence. The DC microgrid is generally utilized for private and static loads where a power line is utilized as the correspondence medium [33,34].

4.3. *Florida International University microgrid test-bed*

The Florida International University (FIU) microgrid test-bed is a mixed fittings and programming system with correspondence bases to explore microgrid systems. The microgrid equipment foundation embodies four AC generators (G1 works at consistent recurrence to look after the recurrence of the system, while the remaining generators work under torque control) in a loop topology with adjustable loads, which connect through load transports and diverse length displayed transmission lines. Lines are ensured by wires to counteract damage to the parts and are intended for 132.8 V, 15 A for every stage. Fig.15 displays a solitary line chart of actualized microgrid setup. The synchronous generators are 13.8 kVA and 10.4 kVA at 60-Hz with an AVR to save a yield voltage greatness [35].

The correspondence system holds screening DAQs that procure and send the information through TCP/IP conventions, which permits the execution of supervisory control and information acquisitions (SCADA), manual and programmed control of the force system, and the capacity to enter the information all around the system from a remote area progressively. A 332 V DC voltage regulates strong state transfer and the DAQs computerized yield where a PC controller could connect this voltage. The constant controller can control any extension according to the generally speaking system technique and continuously followed by voltage and current information. The DC transport is associated with the AC system through a bi-directional converter enables bi-directional power flow between AC and DC. The system comprises a DC-DC converter combining PV energy sources into a normal DC busbar. They can actualize the MPPT on the power flow to the DC system [36].

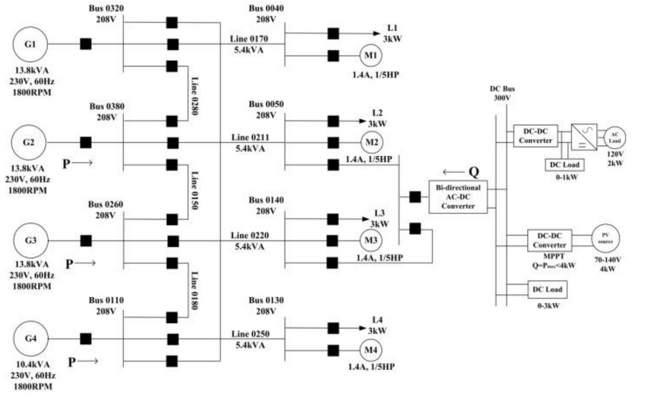

Fig. 15. Schematic diagram of Florida International University microgrid testbed [35].

4.4. University of Texas at Austin at USA

Distributed generation has been arranged by a focal 2 kV DC transport that joins with numerous power sources and an assortment of animated and latent loads. The microgrid dissemination line encompasses over 5m between two labs inside the UT-CEM office to furnish spatial division of the power system components and sensible line impedance values. The microgrid has developed with two free 480V, 60Hz, three-phase utility power supplies associated through transformers with numerous auxiliary windings as shown in Fig.16. The power supply interfaces are situated at both sides of the conveyance line (one for fundamental microgrid lab and the other for gas turbine/high speed generator test cell) [28,29,37]. The Center for Electro-mechanics at the University of Texas at Austin has a supporting hybrid microgrid that can provide power up to 2 MW to interface with the commercial power system and other distributed sources of electric power. It incorporates local prime movers that drive generators, both conventional 60 Hz and high frequency AC (800 Hz), as well as energy storage units.

Numerous grid architectures have been studied and simulated, including a variety of pulsed and intermittent duty loads, which usually exist on US Navy ships. Stability of the DC bus is one of the problems found during the investigation by the influence of constant power loads because of experimental limitation.

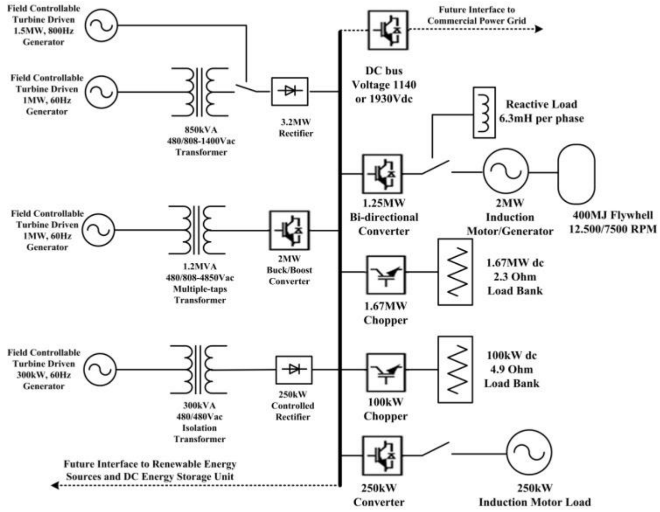

Fig. 16. Schematic circuit of UT-CEM microgrid [25].

4.5. Microgrid test-bed at Albuquerque, New Mexico by Shimizu Institute of Technology (SIT)

The Shimizu Company has been established in 1804 with the end goal of undertaking power system arranging, outlining and office administration, and maintenance and redesign. It created a microgrid test-bed at Albuquerque around 2010.

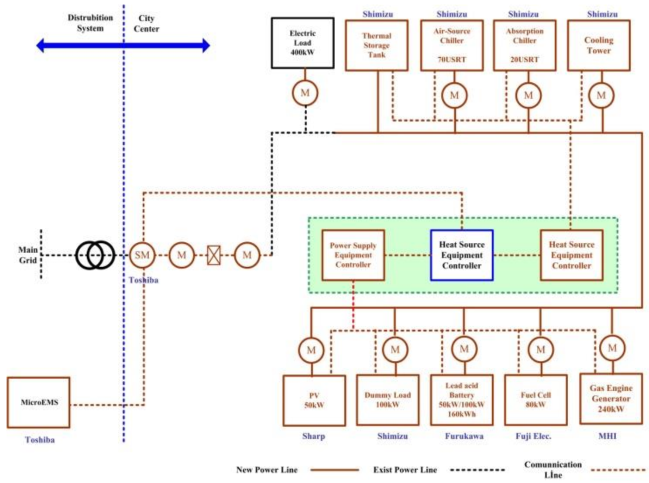

Fig. 17. Microgrid test-bed at Albuquerque, New Mexico by Shimizu Corporation [37].

This SIT test-bed comprises a gas motor generator (240 kW), power module (80 kW), lead corrosive battery (50 kW/100 kW), PV (50 kW), dummy load (100 kW) and line voltage of 400 kW as shown in Fig.17. The office has a building named energy management system (BEMS), heat source equipment/heater controller and power supply supplies controller to manage both supply and interest. This onsite distribution system serves private and business loads with the assistance of power line correspondence [38].

4.6. NEDO Microgrid project at Los Alamos, NM

The vision is to incorporate and plan energy supply from PV and batteries into the general Los Alamos power plant and deal with the PV and battery energies under diverse working conditions. It also aims to achieve reliable power supply from PV/battery under unstable cloud coverage conditions and real time pricing into the charging/discharging of the batteries. Fig.18 illustrates the block diagram of the Los Alamos facility. This US-Japan collaboration microgrid project has 1 MW Japanese PV, 1.8 MW battery, 8.3 MW capacity, and integration and control of Japanese PV technology with micro EMS system on US distribution system [39].

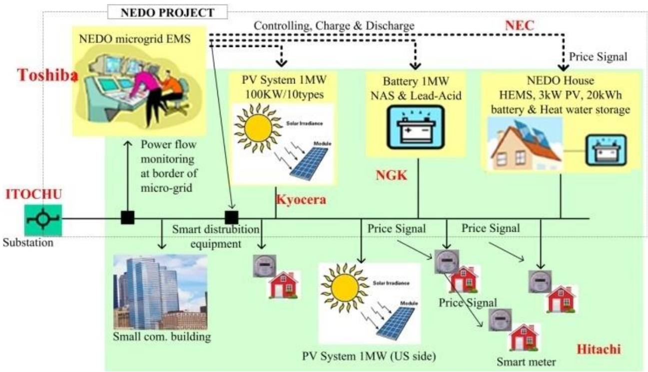

Fig. 18. Block diagram of microgrid facility at Los Alamos [38].

This test-bed also establishes numerous PV penetration levels such as 25%, 50%, etc. on Feeder 16 and it has islanding capabilities for several hours. Variable demand of up to 3.5 MW is required for feeding power of approximately 1,900 customers. This utility microgrid with optical fiber communication line is one of the NEDO projects in North America [39-42].

5. Microgrid test-beds in Western Regions of America

5.1. Sandia National Lab US

Sandia National Laboratories have directed the examination on tests connected with stochastic renewable source and achieved "Empowering Secure, Scalable Microgrids with High Penetration of Renewables" qualified plant for reconciling investigation into informatics, distributed nonlinear control, interchanges, displaying, recreation, and equipment to create empowering devices for configuration, dissection, and execution of force systems [34,35]. Progressed controls and correspondence expanded utility outlines in existence today have relied upon to permit enhanced system execution but also require infiltrated methodology for security. This proving ground depends on an adaptable building design to empower the improvement of numerous topologies, versatile systems, and multi-level control approaches. It comprises one removable diesel generator, two different renewable energy source emulators for wind and solar power, loads, energy storage, and a reconfigurable transmission as shown in Fig.19.

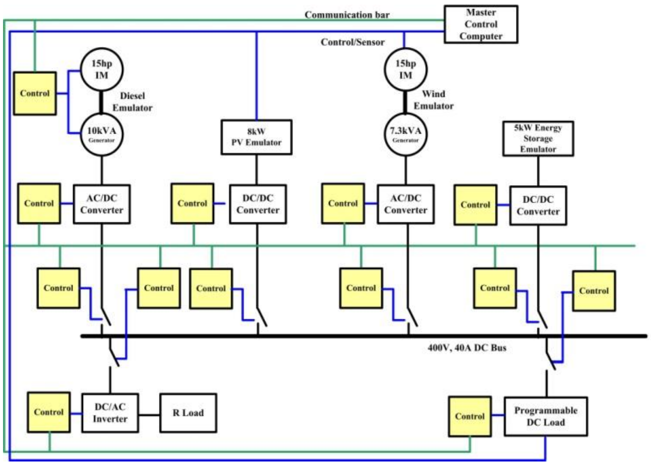

Fig. 19. Block diagram of the Sandia National Laboratories microgrid testbed [33].

This radial type microgrid has first introduced in 2012. There are four essential segments to this system: Master controller, control system, correspondence system, and the distribution line interconnecting all sources, loads, and energy space units in the system. The expert controller performs system introduction, investigation control and client interfacing. The Secure Scalable Microgrid Test Bed (SSMTB) configuration takes into consideration the extent of the system sorts to be worked (DC, single-phase and three-phase AC). A programmable resistive load that provides deterministic and stochastic properties acts as an animated load for an inverter, which can work in steady state or constant power modes of operation. Energy space is incorporated in the structure of an emulator that is equipped for impersonating distinctive sorts of space dependent upon transfer speed, space limits, and top power. The control system stage intends to empower multi-layer control that imparts data through an ethernet interchange system. This proving ground is a remarkably adaptable system empowering the creation and trial approval of new topologies, fittings, controls, correspondence, and security. Deterministic and stochastic parts have incorporated together in the system. The limited idleness of microgrids helps to intensify sensitivities to stochastic segments [33].

5.2. Palmdale water district microgrid facility, California

The 4 MW Palmdale water district microgrid facility was installed in 2006 for the purpose of energy bridging of renewables and DG technologies by integrating wind, hydro and DG in a microgrid using ultra-capacitors. This dissemination system incorporates a 950 kW wind turbine, 250 kW hydro and 250 kW regular gas generators into a microgrid and utilizes a 450kW ultra-capacitor as a space gadget to empower the smooth exchange of renewables and DG advances. This utility sort microgrid has an effect on empowering the development of DG (renewables and microgrids), applying energy space as empowering engineering and furnishing basic missing connections for renewable and DG mix. It intends to improve the profits of clients of the Palmdale district through decreased energy expenses, enhanced system dependability, power assurance, and enhanced power quality and so on. In Fig.20 the block diagram of the Palmdale water district microgrid facility is shown with the medium of communication absent [43,44].

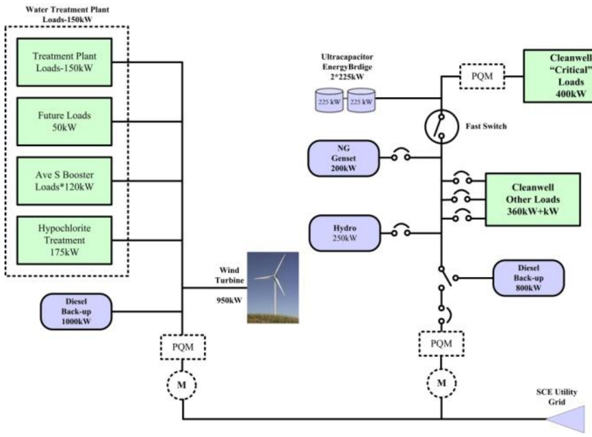

Fig. 20. Block diagram of Palmdale water district microgrid facility, California [42].

6. Microgrid test-beds in Eastern Regions of America

6.1. *Laboratory scale microgrid in New Jersey, USA*

A microgrid feeder has fabricated to serve as a model for demonstrations of microgrid engineering in New Jersey. This exploration has monitored the automation capacities of feeder level circulation, for example, voltage help through V/VAR, low voltage ride through (LVRT) and microgrid shaping competencies. A 12kV/10MVA feeder decreases to a single stage 120V/5kVA comparable for each unit support, as indicated in Fig.21. The substation is supported by a consistent voltage AC source, while loads and PV arrays are introduced at four focuses along the feeder [36,37].

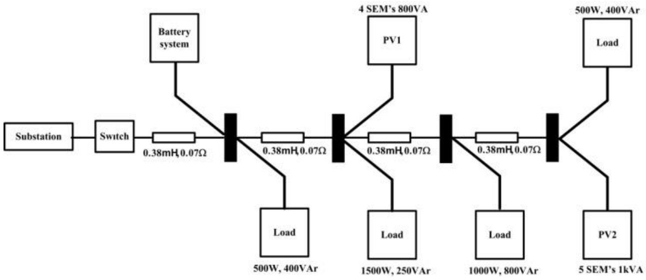

Fig. 21. Laboratory scale microgrid at New Jersey [35,36]

The layout of the feeder consists of four portions of 5% impedance with an X/r proportion of 2.0. This impedance has recreated in the test-bed utilizing air-core wound inductors intended for the fitting parameters. Four load focuses designate as off at the closure of each portion incorporated into the PV system. The total load mounted was 3.42 kVA (68%) at the 0.86 power factor. The aggregate PV was 1.8kW, exhibiting 36% passing through into the circuit. Reproduction showed the viability of V/VAR backing and LVRT, and accompanied by a microgrid test where the circuit exhibited separate and proceeds operations as a purposeful island when confronted with a long haul unsettling influence on the system with the remote correspondence system.

6.2. *Microgrid test-bed at Rochester Institute of Technology (RIT) New York*

Sustainability Institute Hall, the new home of Golisano Institute for Sustainability on the RIT campus, functions in itself as a significant multi-story test-bed for numerous sustainability technologies. The microgrid test-bed provides information about energy generation rates, analyses inherited data, and enables decisions about the actual energy sources at any particular instant.

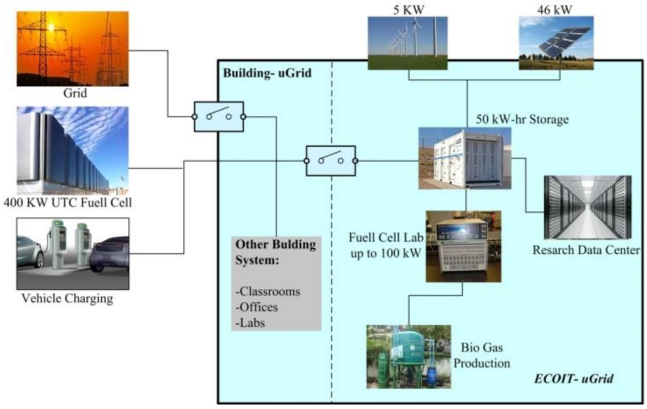

Fig. 22. Block diagram of microgrid test at Rochester Institute of Technology (RIT) New York [40,41].

This facility has several generating units consisting of wind turbines, solar panels, fuel cells, and a 50 kWh battery bank that has an arrangement to increase in size, an eight-well geothermal heating/cooling system, and a 400 kW fuel cell, all overseen by an intelligent microgrid energy tracking system as shown in Fig.22. Liquid (geothermal technology) flows from eight 150-foot profound wells through funnels in the galleria carpet to keep the building warm in wintertime and cool in summertime. The generated power from the RIT facility is used for building lights, electrical outlets and electric vehicle for charging stations [38,43-45].

6.3. Mad River Microgrid at Vermont

The 500 kW capacity Mad river microgrid project was designed, tested and installed at Northern industrial park around 2005. This facility consists of six commercial and industrial facilities, 12 residences, multiple generation assets (280 kW, 100 kW generator sets), microturbines with rated power of 30 kW, photovoltaic array, microgrid isolation switch for islanded operation and controller for overall energy management system. The online diagram of radial type microgrid is shown in Fig.23. Identified requirements and program objectives to be addressed by the Mad river microgrid project are described below [43,45].

Absence of knowledge of administrative organizations and utilities to manage microgrid systems includes:

- Working on administrative and legal issues of real microgrid systems, and creating systems for approaching tasks.
- Demonstrating the operation, insurance, and control of microgrid force systems by utilizing genuine systems.
- Comprehensive information of operation of microgrid systems to amplify the business sector reception.

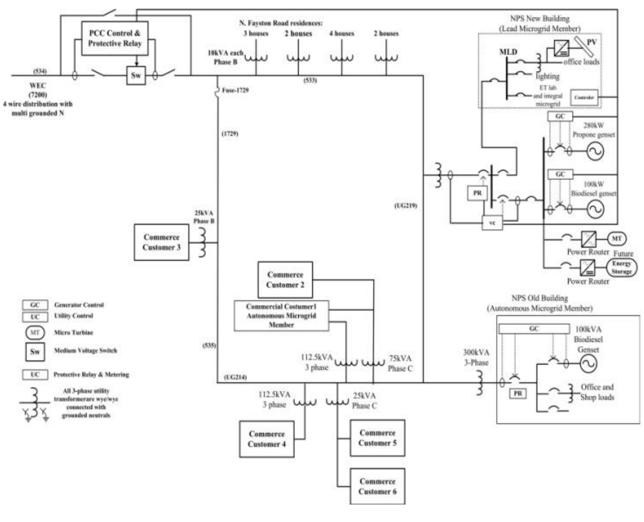

Fig. 23. Online diagram of Mad river microgrid facility at Vermont [44]

Absence of verification/validation of currently accessible demonstration and reproduction strategies for reasonable microgrid systems includes:

- Developing reproduction strategies for streamlining the outline and regard process.
- Model microgrid system and its impact on the appropriation structure.
- Verifying investigation apparatus and displaying strategies utilizing an entirely useful microgrid system.

Absence of institutionalization codes for microgrid (purposeful islanded mode) are:

- Demonstrating safety/protective transferring control strategies for both grid-tied and islanded operations in collaboration with utility accomplice.
- Aligning work with exercises of IEEE1547 purposeful islanding subgroup.
- Providing power and accessibility profits to clients inside the Mad river facility.

7. Findings of the study

The Consortium for Electric Reliability Technology Solutions (CERTS) is the most eminent consortium of North American microgrids [34]. The primary point of this initiative was to enhance working the micro generators together to feed the main grid. Subsequently, three progressed ideas of the CERTS microgrid were the first to actualize and demonstrate how to reduce the field designing exertion on microgrids. An inner assurance strategy is utilized to ensure the microgrid is without flaws and a standard control procedure helps the microgrid to stabilize system voltage and recurrence without correspondence systems [16-19,47-49].

Additionally, the Georgia Institute of Technology and the Distributed Energy Resources Customer Adoption Model DER-CAM at the Berkeley Laboratory have produced several product instruments including a microgrid investigation device for the microgrid system. Usually, there is decentralized control with a space system as demonstrated in Table 1, where the campus type microgrid the most well known in application because on-site generation is still mostly in the R&D stage and researchers continue working on various aspects of it before it can become part of everyday life. Furthermore, nonrenewable DGs and storage systems help to stabilize distributed systems where necessary [16,29].

The greater part of distribution systems is still at the R&D stage with the object of executing approaches for different microgrid types regarding control and assurance. North America has monitored the gathering of renewable energy and concentrated on supporting the robust quality of power sources by incorporating microgrid innovations, as well as the utilization of decentralized control for the regulation of circulation level voltage and recurrence. A complete study on North American microgrids has carried out and shown in Table 2 and Table 3, which will help researchers to find their vital data for planning and examining distribution systems [50-59].

Optimal Power Solutions Inc. has established several microgrid projects in North America recently. Most of these are remote microgrids to provide electricity to isolated communities with available renewable resources.

Several microgrids have installed in a number of North American states since the mid-90s. At the initial stage, diesel engines were the primary electricity source but later various renewable energy resources added to increase the sustainability of the system. These used as either a remote microgrid or utility microgrid to support the main grid.

- The findings of the study can be summarized as follows; CERTS is one of the most effective promoter of MG in North America owing to the advised strategies,
- The universities and institutes in North America accelerate the MG development by implementing several measurement and control instruments, and R&D studies,
- Control methods used in North American MGs are mostly based on decentralized control mechanisms,
- The higher capacity MGs in North America are based on hydro sources that are assisted with diesel non-renewable sources while the capacity of PV and wind source based MGs are less than 1 MW,
- Most of the installed MGs are used to supply the utility grid and load types include residential,
- Although the storage systems are based on batteries, there are some institutional MG applications include capacitor and flywheel based storage systems,
- The surveys also show that MGs installed in Canada have mostly based on hydro and diesel sources instead of renewable sources.

Table 1. Microgrid Test-bed at North America

Microgrid Testbed at North America							
Project Name	**Total Cap. MW**	**DGs Renewable**	**DGs Nonrewable**	**Control Method**	**Microgrid Application**	**Load Type**	**Storage**
Boston Bar – BC Hydro	15	Hydro	Diesel	Decentralized	Utility	Residential	No
Boralex Plant,Qubee	31	NO	Stream	Decentralized	Utility	Residential	No
CERTS Testbed,Ohio	0,2	NO	Gas	Decentralized	Institutional	Residential	Battery
UW Madison Testbed,Wisconsin	0.02	PV	Diesel	Decentralized	Institutional	Static	Battery
VSC feeded Microgrid,Toronto	0.01	NO	Motor	Decentralized	Institutional	Static/Motor/ Electronics	Capcitor
University of Miami Testbed,Florida	0.01	PV,Fuel Cell	No	Decentralized	Institutional	Residential	Battery
Sandia National Lab Testbed ,Washington DC	0.06	PV,Wind	Diesel	Decentralized	Institutional	Residential, Static	Battery
UT Arlington Testbed,Texas	0.01	PV,Wind, Fuel cell	Diesel,Gas	Decentralized	Institutional	Residential, Static	Battery
FIU Testbed,Florida	0.01	PV,Wind, Fuel cell	Motor	Centralized	Institutional	Residential, Motor	FlyWheel
Laboratory scale microgrid testbed,NJ	0.01	PV	No	Centralized	Utility	Residential, Motor	Battery
UT Austin,Texas	5	No	Diesel,Gas ,Motor	Decentralized	Institutional	Static,Motor	FlyWheel
Microgrid testbed at Albuquerque,NM	2.5	PV,Fuel Cell, CHP	Gas	Decentralized	Utility	Residential/ Commercial/ Motor	Capacitor
Utility Microgrid at Los Alamos,NM	2.5	PV	No	Decentralized	Utility	Residential	Battery
RIT Microgrid,New York	0.6	PV,Wind, Fuel cell	No	Decentralized	Institutional	Residential/ Static/ Motor	No
Mad River Park Microgrid,Vermont	0.5	PV	Diesel, Motor	Decentralized	Remote	Residential/ Commercial/ Industial	Battery
Palmdale Microgrid,California	4	Wind, Hydro	Diesel Gas		Utility	Residential/ Commercial /Static,Motor	Capcitor
Ramea wind-diesel Microgrid,NL	3.5	Wind	Diesel	Decentralized	Remote	Residential	Battery

Fortis-Alberta Microgrid,Alberta	7	Wind, Hydro	No	Centralized	Utility	Industial	a
BCIT Microgrid,BC	1.2	PV,Wind	Stream	Centralized	Institutional	Residential,Ind Static,Motor /Electronics	Battery
Hawaii Hydrogen Power park,Hawaii	0.03	PV,Wind, Fuel cell	No	Centralized	Remote	Residential, Static	Battery

Table 2. Microgrid project by Optimal Power Solutions Inc. at North America

Microgrid project of Optimal Power Solutions Inc (OPS) in North America						
Location	**Project Manager**	**Inverter Capacity**	**Renewable Capacity**	**Distributed Generation**	**Application Mode**	**Year**
Superior Valley-USA	Private Client	180kW	120kW	Solar PV	Grid-tied	2010
Over Yonder Cay Island-Bahamas	Private Client	600kW	360kW	PV, Wind, Diesel	Off-grid	2010
Idaho-USA	Idaho Power-US Air Force	150kW	77kW	PV, Diesel	Off-grid	2008
Arizona-USA	APS - Greywolf Project	90kW	40kW	PV, Diesel	Off-grid	2006
Santa Cruz Island, USA	United States Navy	90kW	137kW	PV, Diesel	Off-grid	2005

Table 3. Several small microgrid at North America

Small Microgrid at North America								
Detail			**DGs Non renewable**	**DGs Renewable**	**Storage**	**Microgrid Type Remote[R], Utility[U], Campus[C], AC/DC**	**Total Cap. kW**	**Remarks**
Name	**Country**	**Year**						
Hawii Hydrogen Power Park	USA	2012	No	Wind, PV, Fuel Cell	Battery	R, DC	200	Remote test facility.
Dolan Ohio CM test bed	USA	2002	Genset	No	No	U, AC	60	For emergency supply
Santa Rita Dublin Jail Plant	USA	2011	Diesel	Wind, PV, Fuel Cell	Battery	U, AC	5000	For uninterrupted power
San Juanico Plant	Mexico	2004	Diesel	Wind, PV	No	R,DC	200	For remote community
California Manzanita Hybrid Power Plant	USA	2005	No	Wind, PV	Battery	U,AC	15	For community power supply
Toronto Sunwize Plant	Canada		Diesel	Wind, PV	Battery	R,AC	15	Standby Power system
California Santa Cruz Island	USA	2005	Diesel	PV	Battery	R,DC	300	For US Navy
Xcalac Microgrid	Mexico	1992	No	Wind	Battery	R,DC	150	For village supply
Minnesota Woodstock Microgird	USA	2001	No	Wind, PV	Battery	U,AC	5	For maintaining shop & office
Alaska Kotzebue Microgrid Plant	USA	1997	Diesel	Wind	No	R,AC	11000	For remote area application

Alaska Wales Alaska Power Plant	USA	2002	Diesel	Wind	Battery	R,AC	500	For rural community supply
Alaska St. Paul Plant	USA	1999	Diesel	Wind	No	R,AC	500	For industrial/ airport facility
Ascension Island Plant	Canada	1996	Diesel	Wind	No	R,AC	225	For Island community

8. Conclusion

From the survey of microgrid architectures, it has found that most test-beds are AC microgrids. Conversely, the key point of interest in DC dissemination systems is fewer power quality issues and subsequently fewer parts and less intricate control procedures. Thus, further research is necessary to address power quality issues of the microgrid, additional security, and dependability issues to improve the execution and power nature of microgrid systems. System tied association is paramount when a renewable circulated system is short of space to maintain system steadiness. Furthermore, the survey shows that working together the DOD and universities install most MG test-beds in North America. International cooperation also sees in some plants where Japanese scientists play a role in planning and operating levels. Research shows that diesel generators or battery banks to meet system requirements in worst-case scenarios support almost all MGs. In addition, dummy loads are widely used to prevent overcharge circumstances when the potential loads are idle.

Microgrids have confronted some resistance in industrialized nations, for example,

- Increased entrance of renewable energy
- Technology updates inside the utility
- New systemic effect happening behind the meter

Distributed energy assets will probably turn into the ordinary state; how to coordinate:

- Interconnected numbers of micro generation
- Maintaining grid-tied and islanded modes of operation seamlessly
- Analog-driven power system
- Digital-driven data center

Overall, there is a great deal of interest in MGs in North America supported by governmental and scientific bodies. Thus, it is probable that North America will achieve great impact on distributed generation studies, including renewable resources, up to middle of this century.

References

[1] Peter Asmus, “Why Microgrids are Inevitable”, *Distributed Energy*, p.44-47, September/October 2011,http://www.distributedenergy.com/DE/Articles/Why_Microgrids_Are_Inevitable_15471.aspx

[2] William Pentland, “Grid Problems Boost Fuel Cell Market”, 11/21/2011, http://www.forbes.com/sites/williampentland/2011/11/21/fuel-cells-going-el-fuego/

[3] IEEE&Zpryme Report, “Power Systems of The Future: The Case for Energy Storage, Distributed Generation, and Microgrids”, November 2012, Available at, http://www.admu.edu.ph/sites/default/files/zprymepower systems.pdf

[4] Z. Ye, R. Walling, N. Miller, P. Du, K. Nelson, “Facility Microgrids”, Subcontract Report, NREL/SR-560-38019, May 2005.

[5] Z. Ye, R. Walling, L. Garces, R. Zhou, L. Li, T. Wang, “Study and Development of Anti-Islanding Control for Grid-Connected Inverters”, NREL/SR-560-36243, May 2004.

[6] Peter Asmus, Kerry-Ann Adamson, “Military Microgrids Stationary Base, Forward Operating Base, and Mobile Smart Grid Networks for Renewables Integration, Demand Response, and Mission-Critical Security”, Research Report Pike, 2012.

[7] Chris Marnay, Ryan Firestone, “Microgrids: An emerging paradigm for meeting building electricity and heat requirements efficiently and with appropriate energy quality”, Lawrence Berkeley National Laboratory, 2007.

[8] Ward Bower, Dan Ton, Ross Guttromson, Steve Glover, Jason Stamp, Dhruv Bhatnagar, Jim Reilly, “The Advanced Microgrid Integration and Interoperability”, Sandia National Laboratories, 2014.

[9] Su, Wencong, and Jianhui Wang. " Energy Management Systems in Microgrid Operations," *The Electricity Journal* Volume 25, Issue 8, October 2012, Pages 45–60

[10] Nikos Hatziargyriou, Hiroshi Asano, Reza Iravani, Chris Marnay, “Microgrids: An Overview of Ongoing Research, Development, and Demonstration Projects”, *IEEE Power & Energy Magazine*, pp.73-94, july/august 2007, http://www.hnei.hawaii.edu/research/hawaii-hydrogen-power-park

[11] Farid Katiraei, Chad Abbey, Susan Tang, Maude Gauthier, “Planned Islanding on Rural Feeders – Utility Perspective”, *Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century*, pp. 1-6, Pittsburgh, PA, 2008.

[12] R. H. Lasseter, J. H. Eto, B. Schenkman, J. Stevens, H. Vollkommer, D. Klapp, E. Linton, H. Hurtado, and J. Roy, “CERTS Microgrid Laboratory Test Bed,” *IEEE*

Transactions on Power Delivery, vol.26, no.1, pp.325-332, Jan. 2011.

[13] Lubna Mariam; Malabika Basu; Michael F. Conlon; “A Review of Existing Microgrid”, *Architectures Journal of Engineering*, pp.1-8, 2013.

[14] N.W.A. Lidula, A.D. Rajapakse, “Microgrids research: A review of experimental microgrids and test systems”, *Renewable and Sustainable Energy Reviews*, vol. 15, no. 1, pp. 186-202, January 2011.

[15] Taha Selim Ustun, Cagil Ozansoy, Aladin Zayegh, “Recent developments in microgrids and example cases around the world—A review”, *Renewable and Sustainable Energy Reviews*, vol. 15, no. 8, Pages 4030-4041, October 2011.

[16] Maude Gauthier, “Planned islanding on rural feeders — utility perspective”, *2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century*, pp.1-6, 20-24 July 2008

[17] Joseph H. Eto, “Certs Microgrid Laboratory Test Bed”, *Lawrence Berkeley National Laboratory*, pp.1-71, February 2009.

[18] Krishnamurthy, S.; Jahns, T.M.; Lasseter, R.H., "The operation of diesel gensets in a CERTS microgrid," *2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century*, pp.1-8, 20-24 July 2008.

[19] Charles K. Sao, and Peter W. Lehn; “Control and Power Management of Converter Fed Microgrids”, *IEEE Transactions on Power Systems*, vol. 23, no.3, pp. 1088-1098, August 2008.

[20] R. Teodorescu, “Industrial PhD course on Microgrids “Microgrid Overview”, Alborg University, http://www.et.aau.dk/

[21] R. P. Raffaelle, A. F. Hepp, G. A. Landis, and D. J. Hoffman, "Mission applicability assessment of integrated power components and systems," Progress in Photovoltaics: Research and Applications, vol. 10, pp. 391-397, 2002.

[22] http://www.uwig.org/DWSW2013/UWIG_HOMER_Energy.pdf

[23] J. Eto, R. Lasseter, B. Schenkman, J. Stevens, H. Volkommer, D. Klapp, E. Linton, H. Hurtado, J. Roy, N. Lewis. 2008. CERTS Microgrid Laboratory Test Bed.(California Energy Commission CEC-500-03-024)

[24] Hatziargyriou, N.; Asano, H.; Iravani, R.; Marnay, C., "Microgrids," IEEE Power and Energy Magazine, vol.5, no.4, pp.78-94, July-Aug. 2007.

[25] B. Buchholz, A. Engler, N. Hatziargyriou, J. Scholtes, U. Schluecking, and I. Furones Fartos, “Lessons learned: European pilot installations for distributed generation. An overview by the IRED cluster,” CIGRE 2006, Paris, August 2006, paper C6-302.

[26] H. Farhangi, "Intelligent Micro Grid Research at BCIT," Proc. IEEE Canada Electric Power Conference (EPEC), pp. 1-7, Oct. 2008.

[27] Aki, H., "Independent hybrid renewable energy systems: Example applications around the world," 2010 IEEE Power and Energy Society General Meeting, pp.1-4, 25-29 July 2010

[28] Uriarte, F.M.; Gattozzi, A.L.; Herbst, J.D.; Estes, H.B.; Hotz, T.J.; Kwasinski, A.; Hebner, R.E., "A DC Arc Model for Series Faults in Low Voltage Microgrids," IEEE Transactions on Smart Grid, vol.3, no.4, pp.2063-2070, Dec. 2012.

[29] Z. Jiang, and Roger A. Dougal, “Hierarchical Microgrid Paradigm for Integration of Distributed Energy Resources,” IEEE Conferences, Page: 1-8, 2008

[30] Zhenhua Jiang; Dougal, R.A.; “Hierarchical Microgrid Paradigm for Integration Of Distributed Energy Resources”, 2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, pp.1-8, 20-24 July 2008.

[31] Jay P. Kelley, David A. Wetz, James A. Reed, Isaac J. Cohen, Gregory K. Turner, Wei-Jen Lee "The impact of power quality when high power pulsed DC and continuous AC loads are simultaneously operated on a MicroGrid testbed," 2013 IEEE Electric Ship Technologies Symposium (ESTS), pp.6-12, 22-24 April 2013

[32] S. Glover, J. Neely, F. White, P. Foster, O. Wasynczuk, S. Pekarek, B. "Secure Scalable Microgrid Test Bed at Sandia National Laboratories," *2012 IEEE International Conference on Cyber Technology in Automation, Control, and Intelligent Systems (CYBER)*, pp.23-27, 27-31 May 2012.

[33] Salehi V, Mohamed A, Mohammed O A, "Implementation of real-time optimal power flow management system on hybrid AC/DC smart microgrid," *2012 IEEE Industry Applications Society Annual Meeting (IAS)*, pp.1-8, 7-11 Oct. 2012.

[34] Hussam Alatrash, Ruba A. Amarin, Cheung Lam, "Enabling Large-Scale PV Integration into the Grid," *2012 IEEE Green Technologies Conference*, pp.1-6, 19-20 April 2012.

[35] Herbst, J.D.; Gattozzi, A.L.; Ouroua, A.; Uriarte, F.M., "Flexible test bed for MVDC and HFAC electric ship power system architectures for Navy ships," *2011 IEEE Electric Ship Technologies Symposium (ESTS)*, pp.66-71, 10-13 April 2011.

[36] Atsushi Denda, “Smart Grid Demonstration in Commercial Areas in Albuquerque, NM”, September, 2010.

[37] http://www.4thintegrationconference.com/downloads/16_SG%20Post%20Workshop_Albuquerque%20uGrid_Shimz.pdf

[38] Rafael De La Torre, “Nedo/Los Alamos Collaborative Microgrid Research Project”,

http://www.nnmcab.energy.gov/7-presentations/LACNEDOPresentationforJune15V2.pdf

[39] Hideki Hayashi, "Smart Grid Demonstration In Los Alamos", *4th International Conference on Integration of Renewable and Distributed Energy Resources*, http://www.smartgrid.epri.com/doc/14_SG%20Post%20Workshop_LosAlamos%20uGrid_Hayashi.PDF

[40] Farhadi, M., Mohamed, A. and Mohammed, O., "Connectivity and Bidirectional Energy Transfer in DC Microgrid Featuring Different Voltage Characteristics," Green Technologies Conference, 2013 IEEE, Denver, CO; DOI:10.1109/GreenTech 2013.45.

[41] Yan Yang and Williams, E.,"Theoretical efficiency and asymptotic cost of grid-connected photovoltaic systems," Sustainable Systems and Technology, 2009. IEEE International Symposium on; DOI: 10.1109/ISSST.2009.5156745.

[42] EPRI. Micro Grid Energy Storage Demonstration. CEC/DOE Energy Storage Collaboration. http://energystoragedemo.epri.com/cec/microgrid/microgrid.asp 1 November 2009.

[43] Chris McKay, "Ultra-capacitor Energy Bridge UPS for Palmdale Water District", DOE/ESS PEER Review November 3, 2006 Northern Power Systems, Inc.

[44] Jonathan Lynch, "CERTS MicroGrid Symposium, Northern Power Systems, Update on Mad River MicroGrid and Related Activities", June 17, 2005 Northern Power Systems, Inc.

[45] James Glennie - WEICan and Carl Brothers, Frontier Power Systems, "Wind-Diesel Technology Getting It Right" International Wind-Diesel Workshop, April 23-25, 2008, Ramea, NL.

[46] Farhangi,H., Intelligent Micro Grid Research at BCIT, Electric Power Conference, 2008, IEEE Canada.

[47] Stamp, J. and Stinebaugh, J. , "Microgrid modeling to support the design processes", Power and Energy Society General Meeting, 2012 IEEE.

[48] Lubna Mariam, Malabika Basu, and Michael F. Conlon; "A Review of Existing Microgrid", Architectures Journal of Engineering, pp.1-8, 2013.

[49] Ilhami Colak, Sevki Demirbas, Ibrahim Sefa, Erdal Irmak and H Tolga Kahraman, "Remote controlling and monitoring of HVAC system over Internet", Journal of Scientific & Industrial Research Volume: 67 Issue: 9, Pages: 680-684 Published: SEP 2008.

[50] Eklas Hossain, Ersan Kabalci, Ramazan Bayindir and Ronald Perez "Microgrid testbeds around the world: State of art", Energy Conversion and Management 86 (2014) 132–153.

[51] Eklas Hossain, Ersan Kabalci, Ramazan Bayindir and Ronald Perez "A Comprehensive Study on Microgrid Technology", International Journal of Renewable Energy Research, Vol.4, No.4, 2014 1094–1107.

[52] Eklas Hossain, Sheroz Khan and Ahad Ali "Low voltage power line characterization as a data transfer method in public electricity distribution networks and indoor distribution networks", Electric Power Conference in Canada, 2008. (EPEC) 2008, Pg. No. 1-7.

[53] Eklas Hossain, Sheroz Khan and Ahad Ali "Modeling Low Voltage Power Line as a Data Communication Channel", World Academy of Science, Engineering and Technology) 2008, Vol. 45, Pg. No. 148-152.

[54] Eklas Hossain, Riza Muhida, Ahmad Faris Dzulkipli and Khairul Azizi Abdul Rahman "Solar cell efficiency improvement using compound parabolic concentrator and an implementation of sun tracking system", International Conference on Computer and Information Technology (ICCIT) 2008, Pg. No. 723-728.

[55] Eklas Hossain, Riza Muhida, and Ahad Ali "Efficiency improvement of solar cell using compound parabolic concentrator and sun tracking system", Electric Power Conference in Canada, 2008. (EPEC) 2008, Pg. No. 1-8.

[56] Ersan Kabalci, Ramazan Bayindir and Eklas Hossain "Hybrid microgrid testbed involving wind/solar/fuel cell plants: A desing and analysis testbed", International Conference on Energy Research and Application (ICRERA), 2014, Pg. No. 880-885.

[57] Ramazan Bayindir, Erdal Bekiroglu, Eklas Hossain and Ersan Kabalci "Microgrid facility at European union", International Conference on Energy Research and Application (ICRERA), 2014, Pg. No. 865-872.

[58] Ersan Kabalci, Eklas Hossain and Ramazan Bayindir "Microgrid test-bed design with renewable energy sources", International Conference on Power Electronics and Motion Control Conference and Exposition (PEMC), 2014, Pg. No. 907-911.

[59] Eklas Hossain, Ramazan Bayindir, Ersan Kabalci and Erdal Bekiroglu "Microgrid facility at European union", International Conference on Energy Research and Application (ICRERA), 2014, Pg. No. 873-879.