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Microgrid facility around Asia and Far East

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***Abstract*— The surprising rates of electrification have experienced numerous populated counties in Asian region such as Bangladesh, Indian, China and Indonesia. To meet the increased demand for both power and grid services across the region will require innovation approach and the term discrete power system microgrid has introduced. As the reliability and quality of power demand have increased day by day, power industry faces many problems including rising cost of energy, power quality and stability, aging infrastructure, mass electrification, climate change and so on where people have focused on low voltage or medium voltage distribution generation. Microgrid has served several goals for the society in term of reliability, sustainability and economic power operation. Besides, feasibility of microgrid is wide spread such as various region of underdeveloped Asian subcontinent especially in remote village and Islands. This paper has a detail description of perspective and existing microgrid around this region and its future application. Moreover, the information of microgrid has tabulated here so that researcher and designer would get help from it along with they might know what have done so far in this field and what is going up. The market of microgrid has increased dramatically since last decade and government has focused on quality of community life by harvesting maximum renewable power.**

Keywords— microgrid; distributed generation;

I. INTRODUCTION

The growth of centralized large electric power systems has decline due to the concern of environmental impacts and transmission problem with the rapid increases of on-site power generation. Administrations and commercial ventures have focused on reducing greenhouse gas emission by installing and using every possible renewable resources. As the energy demand increase, we need an efficient power system where the transmission less distribution generation (DG) term has introduced. Usually, DG consists of several renewable energy sources (RES) such as wind, solar etc. which are clear and sustainable energy resources. Therefore, states and energy regulation authorities have inspired people to focus on RE in worldwide. Conversely, higher penetration grid tied DG systems of non-inertia microsources such asfuel cells, PV panels, batteries and inertial microsources such as wind turbines, diesel generators, and flywheels have impact on radial type grid that are exposed to several problems during normal and faulty operation. Researchers have been working on various aspect of microgrid such as power quality, circuit protection coordination, and stability, reliability concerns since last decade to provide reliably, efficiently and cost-effectively distributed electric power systems called as microgrid. A microgrid, which is small unit of power system, has facility to coordinate and manage DGs by using decentralized control so that the necessity of centralized control and coordination becomes less and thus reduce the greenhouse gas effect. However, there are still many research and improvement need to be done before microgrids can take over from traditional power system [1, 2].

In this paper a detailed literature review has been done and status of various microgrid facilities around Asian and Far East region have been presented in detailed. It has also stated outlining the existing microgrid projects information in addition to the difficulties and challenges being faced. A summary of the today's research and development effort being carried out for this particular area has also given in this paper. Several comparison tables have presented and clearly showed the available RESs and technologies have been used along with all other technical information which helps researchers and states to comprehensive the new technology and the amount of research need to be done for installing commercially this emerged technology.

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II. MICROGRID TESTBEDS IN JAPAN

Japan has focused on harvesting and utilizing RE systems as much as possible which has threaten on power quality of country due to intermittent nature of renewable resources. Todays, they have formed microgrid to address those power quality issues. New Energy and Industrial Technology Development Organization (NEDO) has funded several project in this region where wind and solar PV are the most popular renewable sources with the help of storage device [2]. However, the most common control technique is centralized control for different load condition as shown in Table 1.

TABLE I. MICROGRID TESTBED AT JAPAN

Microgrid Projects in Japan					
Project Name	DGs_Renewable	DGs_Nonrewable	Control	Load	Storage
Aichi Microgrid ,Tokoname	PV,Fuel Cell, Biogas	No	Centralized	Commercial/Industia	a
Kyoto eco-energy Microgrid,Kythnos Island	PV,Wind,Fuel cell	Gas	Centralized	Residential	Battery
Hachinohe Microgrid,Hachinohe	PV,Wind, Biomass	Gas	Centralized	Commercial/Industial	Battery
CRIEPI Microgrid,Akagi	PV	No	Centralized	Static	No
Sendai Microgrid,Sendai	PV,Fuel Cell	Gas	Centralized	Residential/Commercial/ Industial	No
FC-CHP based Plant,Osaka	Fuel Cell	No	a	a	a
Microgrid test facility in Yokohama,Japan	Wind,PV,Biogas	Gas	a	a	Battery
a No data found					

A. *Aichi microgrid project – Central Japan airport city*

The main purpose of Aichi's research was to find a way of minimizing the negative effect of the unstable outputs of DGs that use renewable energy on prevailing electric power systems. In Aichi prefecture, the actual microgrid was constructed at the site of the Expo 2005 Aichi, Japan and then transferred to the Central Japan Airport City in 2006. It is constructed as part of a demonstrative project commissioned by the New Energy and Industrial Technology Development Organization (NEDO). Researchers controlled the DGs output with the intention of balance the supply and demand of the power in the microgrid and smoothed the power flow fluctuation of the systems' output at the connection point. The Aichi microgrid comprises of a power supply system with seven fuel cells of various kinds rated at 1.4MW, PV of 330 kW, and a storage system (NaS battary), that inverters where DGs has been connected [1, 8, 11].

The MCFC (?) fuel consists of high temperature gasified gas, biogas, and town gas which extracted from natural gas. In Fig. 1 the schematic diagram of Aichi microgrid has been shown. Storage device i.e. battery helps to stabilize the voltage. Moreover, a meta-heuristic technique has been used for daily generation plan for radial type Aichi microgrid. This distributed system is mainly for the power supply of commercial and industrial load. A telecommunication network along with power line is used as the medium of communication.

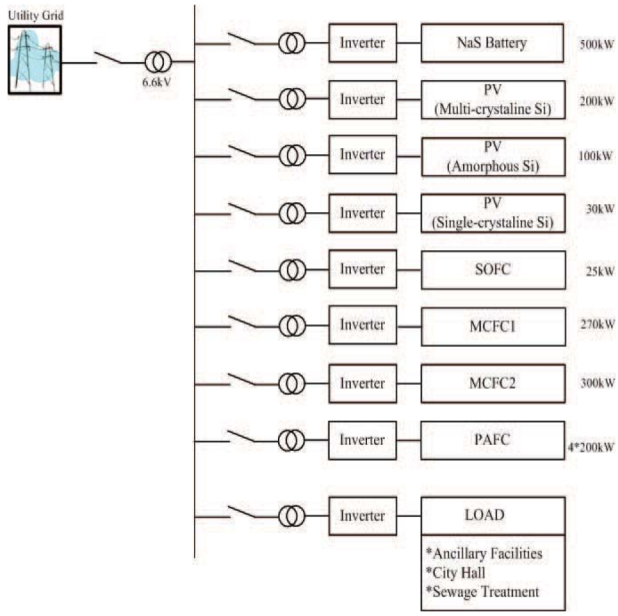

Fig. 1. Online diagram of Aichi microgrid project

B. *Kyotango Microgrid project – Japan*

The virtual Kyotango microgrid project has supported by NEDO group around 2005 as shown in Fig. 2. The microgrid is composed with gas engines, MCFC, lead-acid battery, PV systems and wind turbine. The system has fulfilled demand by remote monitoring and controlling. Integrated Services Digital Network (ISDN) internet connect has been used for the centralized control system and the communication system, which are the solitary connection choices existing in that country region of Japan. The mesh type Kyoto Eco-Energy microgrid is mainly used for residential load and serves the purpose of utility microgrid to support the existent grid [1].

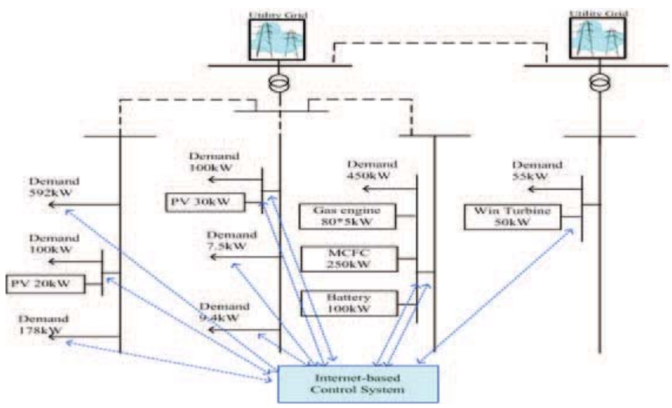

Fig. 2. The schematic diagram of Kyoto Eco-Energy microgrid

C. *Hachinohe project – Japan*

The Hachinohe is one of NEDO microgrid projects that has been installed at 2005 where they installed distribution line meets for both power transmission and communication purpose. The system consists of three gas engines that each of them 170 kW, several PV systems (two 50 kW PV and three 10 kW dispersed) and a small wind farm consists of two 2 kW and two 8 kW dispersed inverters. The microgrid serves seven City of Hachinohe buildings includes four schools and a water supply office. A 100-kW lead-acid battery bank is also equipped shown in Fig. 3. These facilities are interconnected through a 6 kV, 5.4 km duplicate distribution line, with the entire system connected to the commercial grid at a single PCC. The stability of supply and demand has achieved through designed control system. A new PV inverter is mounted and operated that can compensate the imbalances among the three phases. This radial type microgrid is mostly applied for the commercial and industrial purpose to support the existing utility grid [1, 6, 12].

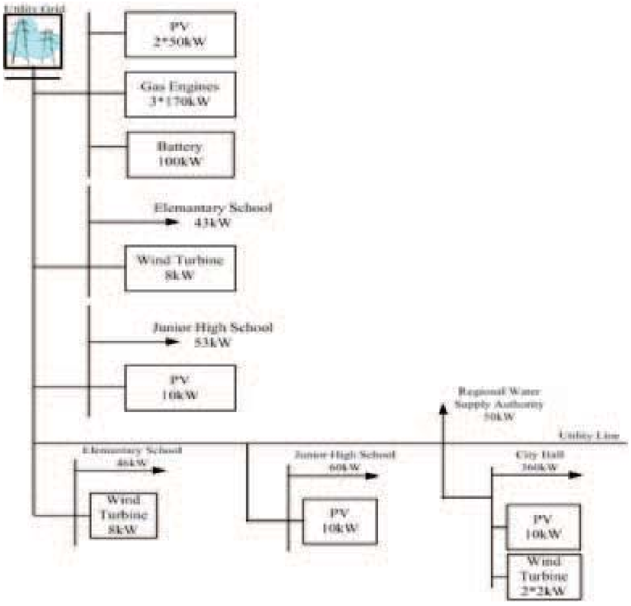

Fig. 3. Online diagram of Hachinohe microgrid project

D. Central Research Institute of Electric Power Industry (CRIEPI) microgrid project at Akagi

The block diagram of CRIEPI microgrid project has shown in Fig. 4 which has intended to assess new test apparatus incorporated with control. This distribution system has three solar modules each of them connected through 100 kW invert and 200 kVA industrial load. A static var compensator (SVC), a step voltage regulator (SVR) and loop balance controllers (LBCs) are also equipped in this system to serve the control purpose without energy storage device in this system. Fiber optics communication system is available for central control system and SVC and SVR help to maintain system voltage. Here in development, different types of LBCs are established one is with transformer (500 kVA mini-prototype) another one without transformer (a new concept model of 1000 kVA) [1, 12].

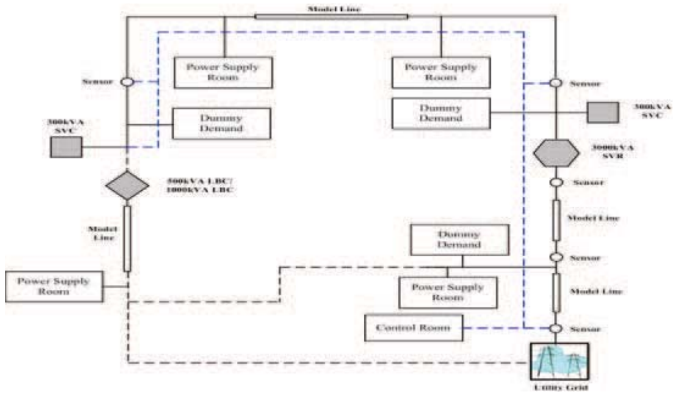

Fig. 4. Structure of test network at Central Research Institute of Electric Power Industry at Japan

E. Sendai project – Japan

NEDO has also supported a microgrid project in Sendai which was accomplished at the end of 2006. The goal of this research is to demonstrate numerous simultaneous PQR supply for the range of customers and the objective of this study can be subdivided as below

- To prove that numerous power quality levels can be provided simultaneously by a microgrid.
- To compare the economic feasibility of the multiple PQR approach compared conventional uninterruptible power supply (UPS) equipment.

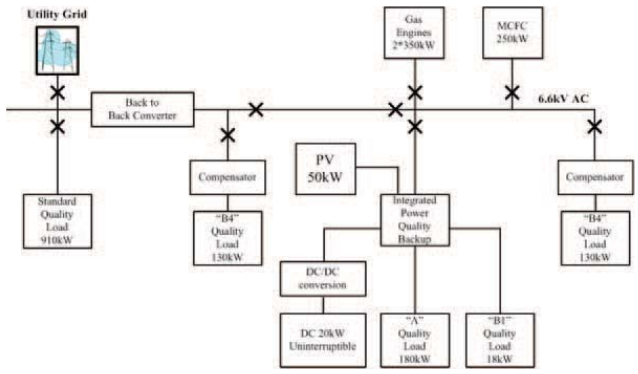

Fig. 5. Online diagram of the Sendai renewable energy project at Japan

The Sendai microgrid system configuration has shown in Fig. 5, which comprises of two 350 kW gas engine generators, a 250 kW MCFC, 50 kW PV, battery energy storage and several types of compensating devices along with remote measurement and control system facilities via GPS. A central controller determines the application mode for a given time. This radial type microgrid is used for residential, commercial and industrial load to support the main grid [1, 6, 9, 11].

III. MICROGRID TESTBEDS IN CHINA

A. Hefei University of Technology (HFUT) microgrid project in China

Microgrid testbed in Hefei University of Technology (HFUT) has been developed to investigate hardware and software design and description of features in single-phase, three-phase and multi AC buses with energy management system, optimum structures, unbalance problems and control strategies of micro-grid with multi-energy Generators (MMEG), a comprehensive TB-MMEG, shown in Fig.6. The testbed of MMEG comprises of two different types of PV generators, two 30 kW wind turbine, and storage devices such as battery bank, fuel cell and ultra-capacitor bank, Gas generators or regular generator for the purpose of simulating hydro/fossil generator various types of loads. There are two different voltage levels in AC buses such as 400VAC and 800VAC to simulate the 35kV voltage level grid, where the length of transmission line is adjustable by putting corresponding resistance during simulation [1, 7, 15].

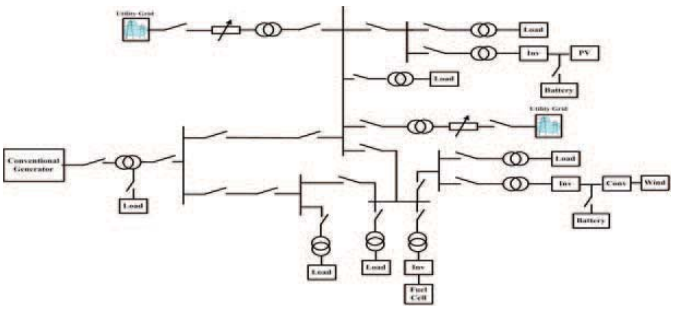

Fig. 6. The schematic diagram of HFUT microgrid testbed.

The responsibility of DG controller is to maintain bus power flow, frequency and voltage stability, seamless transition, power quality issues and protection. This mesh type microgrid is designed for campus and profi bus is used as a communication medium at 2006.

B. Laboratory scale microgrid in Tianjin University – China

Researches in Tianjin University carried out research on the planning and design of the microgrid and DERs, the operation, control and protection of the microgrid and the distribution network with DERs. They have already built a small microgrid experimental system and an integrated microgrid system. The small microgrid experimental system is illustrated in Fig. 7. The single phase system of 230 V, 50 Hz microgrid contains Solar PV System, Wind turbine, battery as a storage device and power electronics interface to interconnect with grid. The microgrid central controller (MCC) is used for the energy management. The system can be operated at two steady-state operation modes such as grid tie mode where DGs work as fixed PQ generators and storage system allows grid following, and islanded mode where storage system is functioned in voltage control mode, and two transient state operation modes such as transition between grid tie mode and islanded mode and vice versa. RS485 lines has been used for communication interface. This campus type microgrid has radial distribution system for both static and motor load of operation [16].

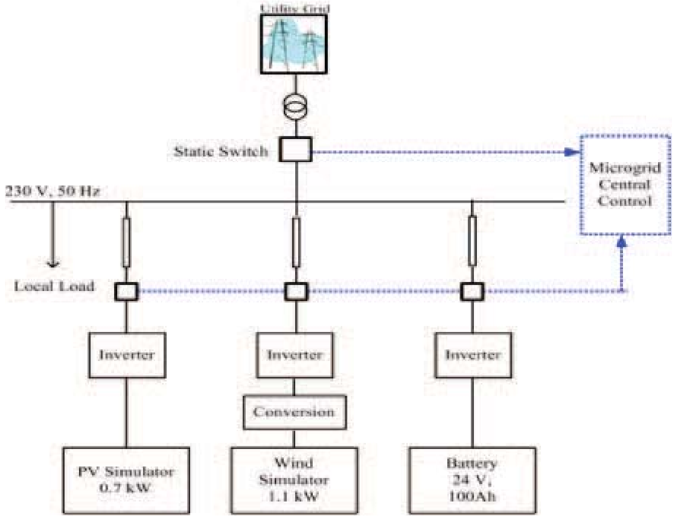

Fig. 7. The schematic diagram of laboratory scale microgrid in Tianjin University

C. NUAA Microgrid testbed NUAA in china

The objective for NUAA testbed is to analyze the smooth transition issue of microgrid system based on master-slave structure, operation principle of phase locked control strategy was studied to realize in digital implementation. A devoted 100 kVA microgrid testbed was built to verify the micro grid control strategy and verified by experiment. In the master-slave configuration based microgrid, there is only one inverter performing as a master inverter, while the others are slaves controlled as current sources. The master inverter usually has two selectable operation modes: current controlled for grid-tied mode and voltage controlled for islanded mode. Test facility consists of a 2kW single-phase photovoltaic inverter, a 17kW three-phase photovoltaic inverter, and a 15kW customer made wind simulation system consisting of a permanent-magnet motor-generator set, 100 kVA passive load bank and a 30kVA active load unit, a programmable wind simulation to drive the motor to simulate different wind turbine performances, and a 15kW three phase grid-tied wind turbine inverter for grid interface as shown in Fig. 8. Here the programmable DC power supplies and wind simulation converter are used in place of actual solar panels and wind turbine to maximize the flexibility of the testbed.

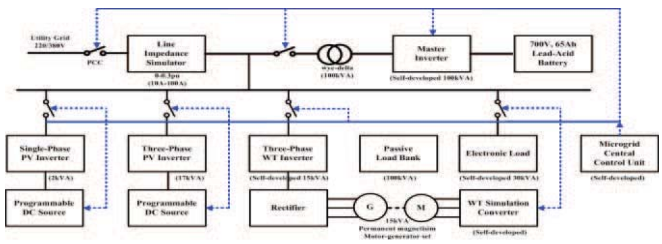

Fig. 8. Block diagram of microgrid testbed NUAA in china

High speed digital signal processor (150MHz FPU) is used for the master inverter, which input is coupled to a 700V lead-acid battery array. A microgrid central control provides various functions as information management and data acquisition, system control of microgrid. A high speed embedded PLC is used as the control platform for information management and data acquisition as a medium of communication [20].

IV. Microgrid Testbeds in the Rest

A. Laboratory scale microgrid at the Institution of Engineering and Technology (IIT) – India

The test microgrid model comprises of two particle swarm optimization (PSO) based fuel cell stacks with power electronics interfaced, an induction generator (2.2 kW, 415 V, 50 Hz, three-phase, 0.85 pf and the rotor is of squirrel cage type). The grid capacity considered for the experimental set-up is 3.2 kVA, 415 V, three-phase and 50 Hz. The schematic diagram of the microgrid test setup is illustrated in Fig. 9. The control of voltage and frequency has been achieved by the PWM inverter. The system has no communication system or storage device [17].

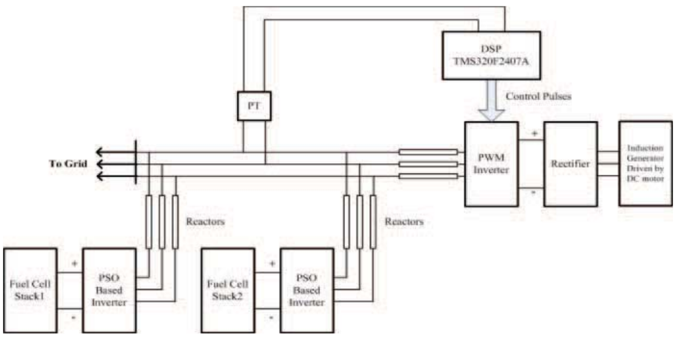

Fig. 9. Test microgrid at IET in India.

B. Wani area Microgrid in India

In Maharashtra State Electricity Distribution Company Ltd (MSEDCL) at Wani village has a distributed generation system which consists with 20 MW biomass plant. The plant load factor is 0.89 where a solar PV plant 500 kW has already built. This combined plant has served of 18.5 MW Peak Load which has comparability lower unit prize than conventional grid power. A microgrid could help villager in economic power and power security as well. Fig. 10 and Fig 11 demonstrate renewable generation synchronized with utility grid at Wani village region. The mesh type microgrid is used for various type of load (residential, commercial and industrial) to support the utility grid. Power line serves the medium of communication [5].

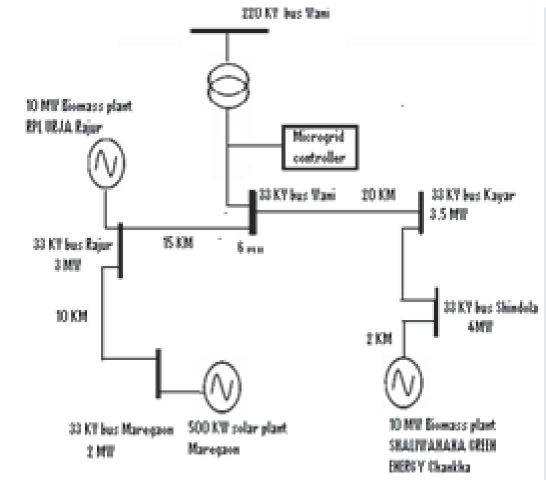

Fig. 10. Prevailed RG synchronized with utility grid

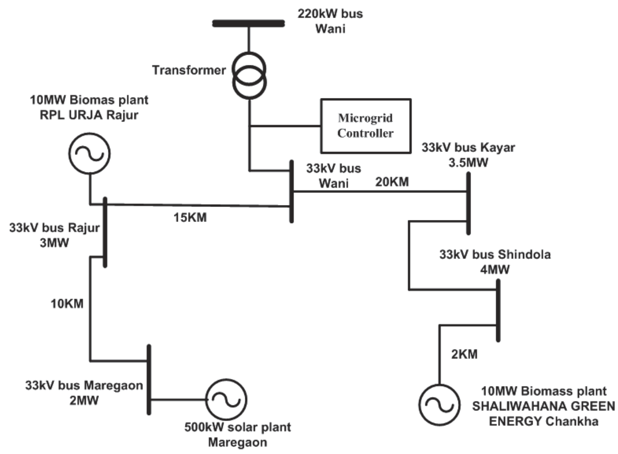

Fig. 11. Proposed microgrid at 33 KV bus Wani

C. Institute of Nuclear Energy Research, Taiwan(INER)

The Institute of Nuclear Energy Research (INER) has designed and implemented the very first outdoor microgrid testbed in Taiwan at 2009 whose capacity is 512.5 kW. This radial type microgrid consists of battery, high concentration PV (HCPV), wind turbine generator (WTG) and gas turbine generator. The goal of this facility is to demonstrate of the HCPV and WTG developed by the INER and performance analysis of inverter during adverse conditions. In order to demonstrate the nodes of the microgrid noticeably, Fig. 12 illustrates the one line diagram of INER 18 AC buses and 4 DC buses microgrid. The gas turbines operate in P/Q control mode while robust control helps to stabilize the voltage and frequency is achieved by gas turbine inverters in the microgrid. Moreover, the battery system could serve as master controllers for an islanding microgrid and the performance comparison of inverters at both gas turbine generators and battery systems has been conducted. For piloting experiment, INER microgrid used both static load and motor load where power line was used as a communication medium [3, 13, 16].

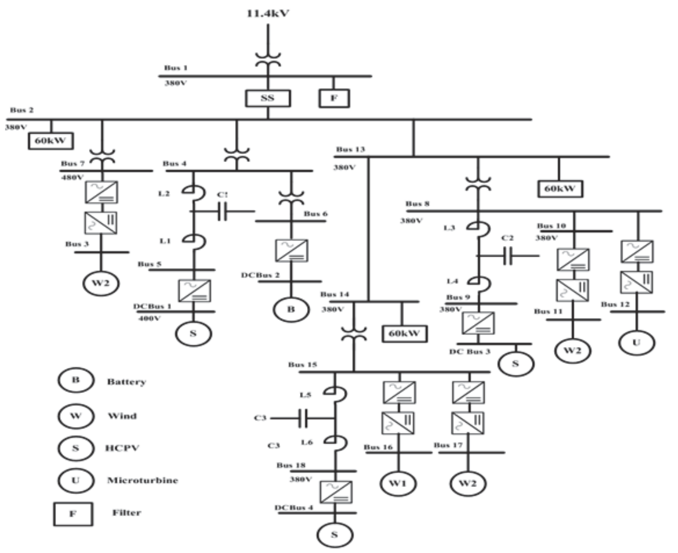

Fig. 12. Online diagram of Institute of Nuclear Energy Research microgrid

D. Microgrid testbed of Queensland University of Technology Australia

The schematic diagram of the microgrid system under development is shown in Fig. 13 at Queensland University of Technology Australia. The radial type hybrid microgrid consisted of inertial (diesel generator) and converter interfaced microsources (PV, FC and battery) where droop control has been used to balance power. There are various types of load available in this system such as resistive heater loads, induction motor loads, and nonlinear load. Fuel cell helps to improve power quality. The control scheme can change its mode of operation seamlessly depending on the power demand of the nonlinear load without any communication medium. Research shows that low voltage DC distribution system, mainly dependent on PVs, can operate with nonlinear load and residential load of campus network. PVs and converter interfaced renewable source can help to regulate dynamics of microsources system in case of low voltage distribution network [4, 19].

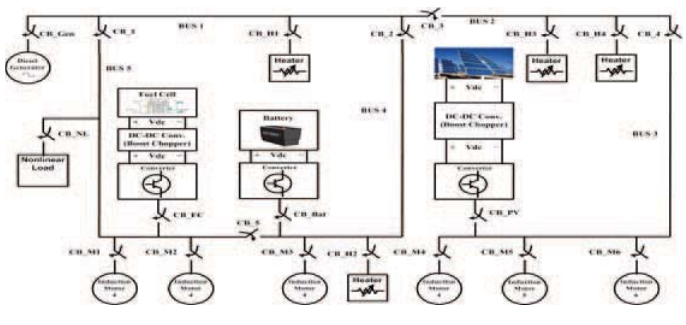

Fig. 13. The schematic diagram of the microgrid at Queensland University of Technology Australia

V. COMPARISON OF ASIAN MICROGRID TESTBEDS

Korea's only and first pilot project is installed by the Korean Energy Research Institute (KERI). The test facility is equipped with PV simulator, fuel cells, diesel generators, wind turbine simulator along with significant, non-significant loads, storage and power quality devices. Besides, a 230 MW microgrid in Jeju Island has installed with wind turbine and fuel cell at 2009. Several microgrid projects have also installed around this region which has shown in Table 2 below [2].

TABLE II. MICROGRID TESTBED IN REST OF THE ASIAN REGION

Microgrid Projects in rest of the world						
Project Name	Detail[Structure/ Power Nature/Type]	DGs_Renewable	DGs_Nonrewable	Control	Load	Storage
HFUT Microgrid,China	Mesh/AC/TestBed	PV,Wind,Fuel cell,Hydro	Diesel	Agent based	Static,Motor	Battery
Tianjin University Testbed,China	Radial/AC/TestBed	PV,Wind		Centralized	Static	Battery
Test Microgrid at IET,India	Radial/AC/TestBed	Fuel Cell	Motor	Centralized	Static	No
MSEDCL at Wani Area Microgrid,India	Mesh/AC/Real	PV,Biomass	No	Decentralized	Residential/ Commercial/ Industial	No
INER Microgrid Testbed,Taiwan	Radial/AC/TestBed/Real	PV,Wind	Gas	Decentralized	Static,Motor	Battery
NUAA Testbed,China	Radial/AC/TestBed	PV,Wind	Motor	Centralized	Static,Motor	Battery
QUT Microgrid Testbed,Australia	Radial/DC/TestBed	PV,Wind	Diesel	Decentralized	Residential, Motor	Battery

Presently, all the microgrids in this region in planning and testing stage and several universities have started doing research in microgrid as states put stress on renewable energy. The Yungngora, Kalumburu and Windorah communities are examples of remote microgrid. Furthermore, some energy companies are currently planning and developing microgrids on several islands for example Thursday Island in Queensland and King Island in Tasmania. The most remote microgrid project is currently going on in Western Australia where wind power is the most popular renewable as shown Table 3 [2].

TABLE III. MICROGRID TESTBED IN AUSTRALIAN REGION

Microgrid projects in Australia			
Microgrid Detail		Primary Energy Resource	Capacity kW
CSIRO, Newcastle	New South Wales	PV	110
King Island	Tasmania	Solar	110
Kings Canyon	Northern Territory	PV	225
Coral Bay	Western Australia	Wind	825
Bremer Bay	Western Australia	Wind	660
Denham	Western Australia	Wind	920
Esperence	Western Australia	Wind	3600
Hopetoun	Western Australia	Wind	1200
Rottnest Island	Western Australia	Wind	600

TABLE IV. LIST OF SELECTED MICROGRID PROJECTS BY OPTIMAL POWER SOLUTIONS INC.

Microgrid facility of Optimal Power Solutions Inc (OPS) around Asia and Far East						
Location	Time	Project Manager	Renewable Capacity	DG_Nonrenewable	DG_Renewable	Application Mode
Maluku & Makassar Islands-Indonesia	2012	PLN Utility, Indonesia	700kW	Diesel	Solar PV	Off-grid
Maluku Islands-Indonesia	2012	PLN Utility, Indonesia	225kW	Diesel	Solar PV	Off-grid
South India	2012	BHEL	10MW	No	Solar PV	Grid-tied
India	2012	BHEL, India Bulls	6MW	No	Solar PV	Grid-tied
Lakshadweep, Bangaram Islands-India	2012	BHEL	2MWp	Diesel	Solar PV	Off-grid
Marampit Province-Indonesia	2012	PLN Utility, Indonesia	150kWp	Diesel	Solar PV	Off-grid
Maluku Province-Indonesia	2012	PLN Utility, Indonesia	405kW	Diesel	Solar PV	Off-grid
Morotai Island, Moluccas-Indonesia	2011	PLN Utility, Indonesia	600kW	No	Solar PV, Battery	Off-grid
Raichur, Karnataka-India	2011	BHEL, India	3MW	No	Solar PV	Grid-tied
Bunaken, Indonesia	2011	PLN Utility, Indonesia	353kW	Diesel	Solar PV	Off-grid
Karnataka-India	2010	KPCL-State Utility	3MW	No	Solar PV	Grid-tied
Kinabatagan, Sabah-Malaysia	2010	KKLW Rural Ministry	220kW	Diesel	PV	Off-grid
Raj Bhavan Governor House-Kolkata	2009	WBGEDCL, Ministry of New & Renewable Energy	1kW	No	Solar PV	Grid-tied
Jamuria-West Bengal	2009	Disargarh Power Corporation (DPC)	2MW	No	Solar PV	Grid-tied
Telupid, Sabah (Malaysia)	2009	Ministry of Education Malaysia	100kW	a	Hybrid Power Conditioner	Off-grid
Kalabakan, East Sabah (Malaysia)	2009	TNB-ES, Ministry of Education	250kW	Diesel	PV	Grid-tied
Orang Asli Project-2, Malaysia	2008	TNB-ES Malaysia	45kW	Diesel	PV	Off-grid
Hyrid Power Systems-Indonesia	2007	PT Len	200kW	Diesel	PV	Off-grid
Indonesia	2007	PT Nabgunbaskara	30kW	a	Hybrid Power Conditioner	Off-grid
Orang Asli Project-1, Malaysia	2007	TNB-ES Malaysia	138kW	Diesel	PV	Off-grid
Villages Sabah Power Systems, Malaysia	2007	TNB-ES Malaysia	105kW	Diesel	PV	Off-grid
PulauTinggi, Mersing-Malaysia	2007	TNB-ES Malaysia	40kW	Diesel	PV	Off-grid
Perhentian Island-Malaysia	2007	TNB-ES Malaysia	280kW	Diesel	PV, Wind and Diesel	Off-grid
School Sabah Power Systems-Malaysia	2007	Ministry of Education	190kW	Diesel	PV	Off-grid
Bandung-Indonesia	2006	Alstom	200kW	a	GSC Systems	Off-grid
Lighthouse Locations-Indonesia	2006	Ministry Project	300kW	Diesel	PV	Off-grid
Philippines	2006	Dumalag / Matec	30kW	a	Hybrid Power Conditioners	Off-grid
Lakshadweep Islands, India	2005	BHEL, India	25kW	Diesel	PV	Off-grid
Mersing Islands, Malaysia	2004	TNB-ES Malaysia	85kW	Diesel	PV	Off-grid
a No data is found						

Optimal Power Solutions (OPS) Inc. has developed and implemented renewable microgrid and utility storage projects in various region of the world [10, 11]. Recently, OPS has developed advanced storage equipment suitable for connecting grid, solar, wind and storage as well. Few selected projects have been listed here in Table 4.

Finally in Table 5, we have presented various going and installed project around the Asian and Far East region.

TABLE V. SUMMARY OF MICROGRID PROJECTS IN ASIAN AND FAR EAST REGION

Microgrid Facility around Asia and Far East							
Name	Country	Year	Total Capacity	DGs_Nonrenewable	DGs_Renewable	Storage	Microgrid Type
FC-CHP based Plant	Japan	2009	300 kW	No	Fuel Cell	No	Campus, AC
Microgrid test facility in Yokohama	Japan	2008	100 kW	Gas	Wind, PV, Biogas	Battary	Remote, AC
CSIRO Energy center	Australia	2010	500 kW	Gas	Wind, PV	Battary	Utility, AC
Singapore pulau ubin microgrid	Singapore	2011	1000 kW	Diesel	PV	Battary	Utility, AC
Korea KEPRI microgrid project	Korea	2011	400 kW	Diesel, Gas	PV	Battary	Utility,AC
KERI Microgrid System	Korea	2008	100 kW	Diesel	Wind, PV, Fuel Cell	Battary	Remote,AC
Subax residential microgrid	China	2006	50 kW	Diesel, Gas	Wind, PV	Battary	Remote,AC

VI. CONCLUSION

The authors believe the future power system would be onsite generation system as it is sustainable and absent of greenhouse gas. The power quality and transmitting large amount of power have always been issues especially in Asian subcontinent. Small scale power system can help to overcome those problems. Besides, still huge area of that region is not electrified including a lot of island where microgrid would be only solution. The literature paper would help to think research and government what the opportunity available is there and how to achieve those. In private sector and university level, few projects are current going on for harvesting renewable energy with a high growth rate.

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