An Appraisal of Microgrid Project Implementations in the East & South-East Asia

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ABSTRACT

A drift in today's power generation system is showing up globally where more and more renewable energy conversion units are located close to the consumers of energy and large units are partially replaced by smaller ones. In the last decade, technological innovations and a changing economic and regulatory environment have resulted in an increased interest in Distributed Generation and hence the Micro Grids. A lot of research and implementation have been accomplished in the area of distributed generation which summarizes that Microgrids are the best solution to exploit the full renewable energy potential.

Down to earth in the developing countries a Microgrid enables small communities to take control of their energy use through a new and innovative way of generating and managing electricity. Although the research and activity of Microgrids, has not yet reached significant levels even across the globe, it is experiencing a rapid growth nevertheless.

This appraisal has accumulated the issues and challenges associated with practical implementations of Microgrids, and so the large scale deployment of the Renewable Energy Technologies, in some developing countries in Asia. The paper specially exhibits the state-of-the-art and the successful development of Microgrids in the East & South East Asia especially at Japan, China, Korea, Malaysia and Singapore.

Keywords: Micro-Grid Implementation, Micro-Grid Projects in Asia, Micro-Grid Research, Micro-Grid Schematics.

INTRODUCTION

A United Nations (UN) estimate says that currently, renewable energy provides 19% of the global energy consumption which with appropriate policies and governmental initiatives could help meet three fourths of the global energy requirements by 2050. More over the Micro grids can increase the reach to over 1.4 billion people who have no access to energy [1]. Renewable Energy Generation, Energy Storage Solutions and Strategically Selected Software Control integrated as a Micro Grid can offer enormous potential to the distributed end users all over. Microgrids can provide improved electric service reliability and better power quality to end customers and can also benefit local utilities by providing

dispatch able load for use during peak power conditions or allowing system repairs without effecting customer loads. The microgrid system has a great potential in remote un-electrified locations, military bases, large commercial as well as industrial complexes, hospitals, shopping malls, apartments, residential complexes, educational institutions etc [2].
In this paper the microgrid technological activities over East & South East of the continent Asia has been presented. Actual field test projects in has been concisely presented as various case studies of distributed generation and microgrids deployment.

ISSUES & CHALLENGES OF MICROGRIDS

A microgrid combined with power electronic interface producing the concept of the future network technologies is a completely self-sufficient network, with preferably autonomous control, communication and protection, capable of providing capacity support to the transmission grid while in grid-connected mode, and with capacity in excess of coincident peak demand. Although clear benefits of Microgrids are undisputable, there is considerable difficulty and key technical challenges to quantify them. The major technical challenges associated with the operation and control of Microgrids are summarized here.

- Coordinated control of a large number of distributed sources with probably conflicting requirements
- Limited communication imposes the adoption of distributed intelligence techniques
- Management of instantaneous active and reactive power balances, power flow and network voltage profiles
- Microgrids are dominated by inverter interfaced distributed sources that are inertia-less while traditionally, power grids are supplied by sources having rotating masses which are essential for the inherent stability of the systems.
- Maintaining stability and power quality in the islanding mode of operation requires the development of sophisticated control strategies which need to be included on both generation and demand sides.
- Transitions from interconnected to islanding mode of operation are likely to cause large mismatches between generation and loads, posing a severe frequency and voltage control problem.
- Instable operation during faults and various network disturbances may occur if Storage components are not there.
- High resistance to reactance ratio of the low voltage networks, resulting in strong coupling of real and reactive power. Hence the control of voltage and frequency can no longer be considered separately. [3].

MICROGRID IMPLEMENTATION IN THE EAST ASIA

In recent years there have been several highly successful microgrid demonstrations in developed countries in Europe and North America. There have been remarkable renewable energy microgrid projects implementations across the East Asia specifically at Japan, China and Korea. It’s a matter of great pride for East Asia as Japan stands on the similar footing to the advanced countries which has been expressed by many reports like “Traditional U.S. microgrid service is very good, and in some developed economies, notably Japan, it’s excellent”[1]

MICROGRID IMPLEMENTATION IN JAPAN

Japan is seen to be the current leader in microgrid projects implementations in the developing countries. The Japanese government has set determined targets for increasing the contribution of renewable energy sources, but this lays the country's hard-earned sky-scraping power quality status in trouble. The Renewable Energy systems existing in Japan are mainly wind turbines and solar PV systems whose intermittent nature is a further stumbling block. As a solution the Micro grid's nice ability to address these problems has fuelled the development of many such test projects.
In Japan the New Energy and Industrial Technology Development Organization NEDO and the Ministry of Economy, Trade and Industry started three demonstrations at: Aichi, Aomori and Kyoto, under its regional power grid with renewable energy resources project in 2003. In these three NEDO projects control systems capable of matching energy demand and supply for microgrid operation were established. An important target in all of the projects is achieving a matched supply and demand of electricity [4].

Aichi Microgrid project – Central Japan airport city

The first project, Aichi microgrid, built as part of a demonstrative project commissioned by NEDO started operation in 2005 World Exposition. Later it was shifted from Aichi to Tokoname City near Nagoya in 2006.In the Aichi project the power resources put into use are solar PV, Fuel cells, plus a battery storage system, all equipped with converters. A single line diagram of the generation system for the project is shown in Figure 1and the specifications are as follows. The installed PV system has total capacity of 330 kW with different cell types multi-crystalline silicon, amorphous silicon, and a single crystalline silicon bifacial type. The fuel cells adopted for the system include: One solid oxide fuel cell (SOFC) of capacity25-kW, Two molten carbonate fuel cells (MCFCs) with capacities of 270 kW and 300 kW and Four 200-kW phosphoric acid fuel cells (PAFCs). A sodium-sulphur (NaS) battery is used to store energy within the supply system and it plays an essential role in matching supply and demand [5].

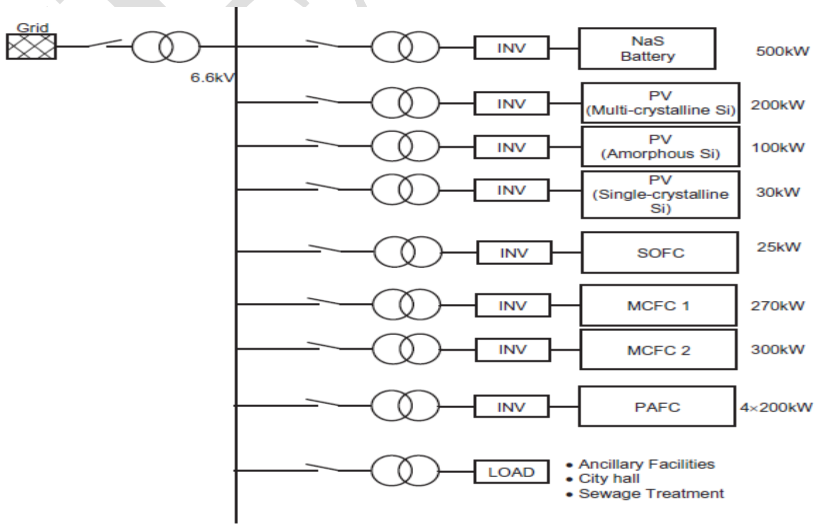

Fig 1. Aichi Microgrid project single-line diagram [5]

Optimized operation is carried and a day-ahead generation planning is done using an optimization technique that applies genetic algorithm and a tabu search meta-heuristic technique. A telecommunication network is used as the medium of communication. The Aichi project microgrid is used to feed some major pavilions and it was put to test twice for grid independent operation mode in 2005 and 2007. Although the first test revealed some deficiencies in controlling the voltage and frequency, the second experiment was more successful.

Kyoto eco-energy project (Kyotango project) – Japan

The second demonstration site under NEDO is in Kyotango where a biogas plant is connected to two PV systems and a small wind turbine. as shown in Fig 2., The microgrid is formed by a plant having gas engines with a total capacity of 400 kW, a 250 kW MCFC and a 100 kW lead-acid battery, and two PV systems and 50-kW small wind turbine connected at remote locations. Each DER and demand site is connected to a substation of the utility grid and they are integrated by a control system only [6].

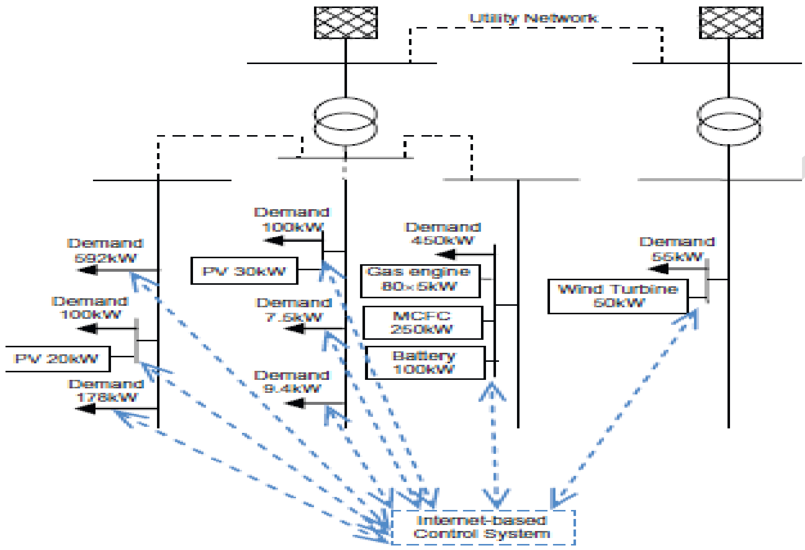

Fig. 2. Kyoto Eco-Energy virtual microgrid schematic diagram [5]

This is considered as a virtual microgrid as it operates as like a VPP virtual power plant. Remote monitoring and controlling is used to meet the energy demand through available power generation. The decisions are made in a central controller and interestingly instead of the latest technology the communication is realized over conventional information networks such as ISDN and ADSL ISP connections to the Internet; may be which are the only connection options available in such an interior rural area of Japan [7].

The Aomori Project in Hachinohe – Japan

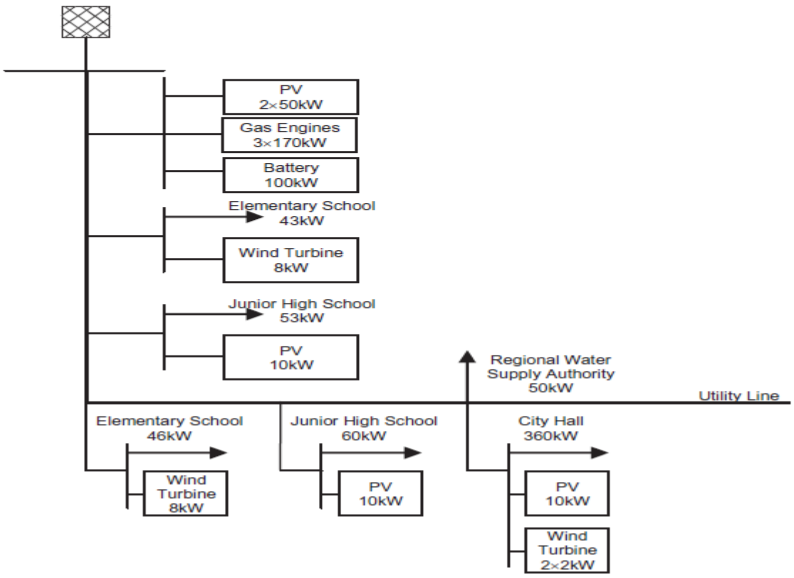

Fig. 3. The schematic diagram of the Hachinohe microgrid [5]

The third project Aomori Microgrid in Hachinohe is carried under NEDO projects is being undertaken by the Mitsubishi Research Institute and Mitsubishi Electric [6]. This system has its private distribution line which is used for both electricity distribution and communication. Four schools and a water supply authority office are connected to the private distribution line. The generation system comprises of a gas engine system (170 kW), several PV systems (50 kW one plant and 10 kW dispersed), a small wind farm (2 kW one plant and 8 kW dispersed) and a 100 kW battery storage. The system is equipped with a wood waste steam boiler because thermal heat was in short supply needed to safeguard the microorganisms that produced digestion gas in the sewage treatment plant. A new PV inverter that could compensate for the imbalances among the three phases is installed and operated. The management scheme developed here ensures stability and meets the building demands. Fig 3 presents the schematic diagram of the Hachinohe microgrid.

Sendai project – Japan

An additional project has been started by NEDO in Sendai city aimed at studying the possibility of supplying different service levels to customers in the same area. Sendai microgrid test system shown in Fig. 4, consist of two 350 kW gas engine generators, one 250 kW MCFC, 50 kW PV, battery energy storage and various types of compensating devices. There is also a remote measurement and control system, which is responsible for monitoring the facilities, GPS synchronized measurement data acquisition, and gas engine output controlling. The applicable mode of operation at a given time is determined by the central controller. The system has power quality backup system which also includes the battery energy storage and a static switch in order to reduce interruptions and voltage drops. The system has enhanced the power quality since it was put into action in 2007 [8].

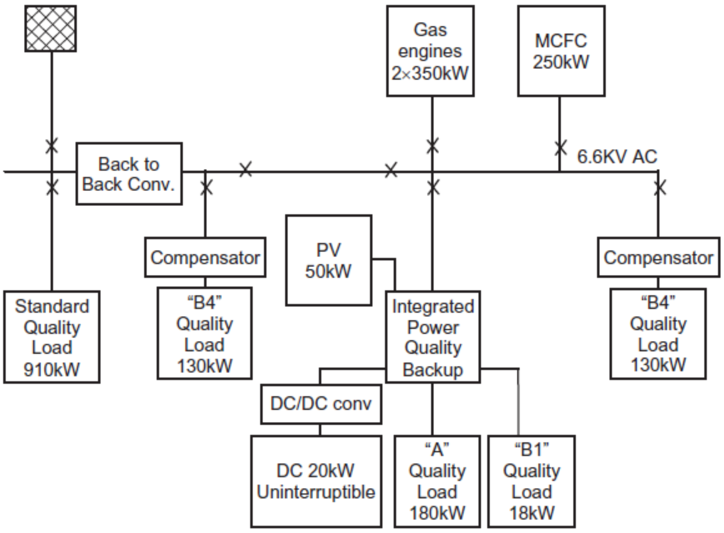

Fig 4. The schematic diagram of the Sendai microgrid [5]

In addition to the NEDO-sponsored projects, there are several private microgrid research projects. Tokyo Gas has been evaluating a 100-kW microgrid test facility since September 2006 at the Yokohama Research Institute, consisting of gas-engine combined heat and power (CHP), PV, wind power, and battery incorporated power electronics.
Shimizu Corporation with the cooperation of the University of Tokyo has developed an optimum operation microgrid control system with a small microgrid that consists of gas engines, gas turbines, PV, and batteries. The system is designed for load following and includes load forecasting and integrated control for heat and power.
Crossing boundaries, Mitsubishi Corporation has installed a small grid in Hsinchiang, China and it can be supplied by distribution network, PV systems, battery storage and genset operation [9].

MICROGRID IMPLEMENTATION IN CHINA

In China many universities are also working successfully on microgrid demonstrations besides the government aided projects.

Microgrid Testbed in Hefei University of Technology, (HFUT) – China

The testbed consists of PV generators 10 kW single-phase and 30 kVA three-phase, three-phase wind generation simulators (30 kW), fuel cell (5 kW), battery bank (300Ah), ultra-capacitor bank (1800F), conventional generators (15 kW) used to simulate the small hydro and small fossil generators and various loads (resistors, capacitor, inductors, AC,DC motors and other electronic loads). AC buses include two voltage levels (400 V, 800 V).
Fig. 5 presents the schematic diagram of the testbed. Controlling is done under two-layers: local controllers and central controller. The local controllers are integrated in the inverters for each DG and they are responsible for controlling feed bus power flow, voltage and frequency, automatic control of seamless operation mode change, power quality control and protection. The test system is managed with an energy management system (EMS) that conforms to the IEC 61970 CIM standards and it comprises of a supervisor control and data acquisition (SCADA) system, automatic generation control and power system application software [10].

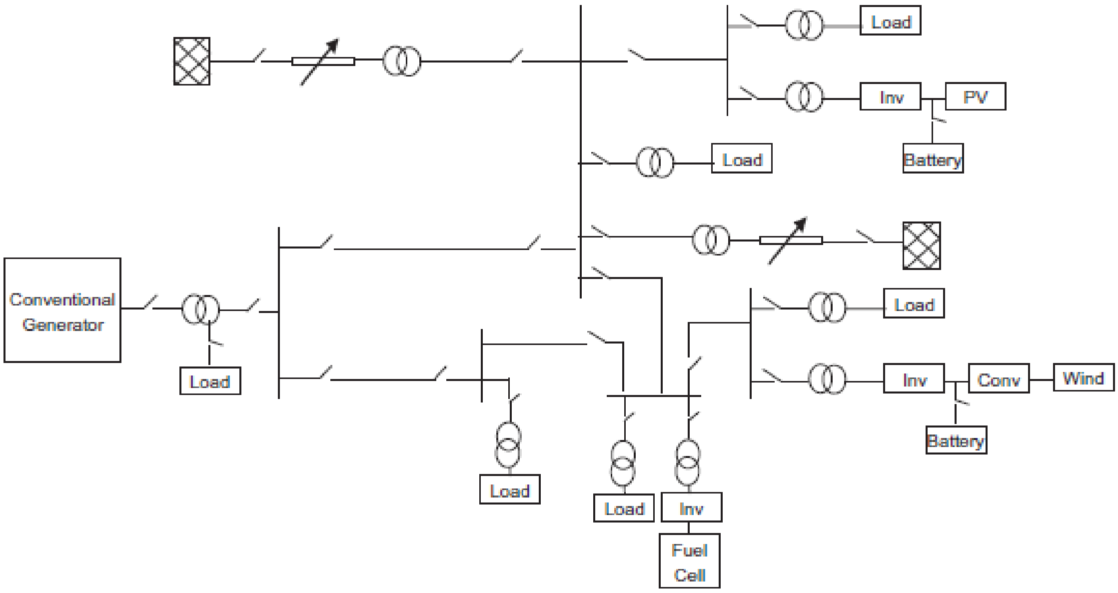

Fig 5. Microgrid testbed in Hefei University of Technology [11]

LABORATORY SCALE MICROGRID –HONG KONG

The Hong Kong microgrid is built attached to a single phase system of 230 V, 50 Hz and it comprises of PV simulator, wind simulator and battery storage. Interconnection of the micro-sources to the grid is made via flexible power electronic interfaces. Fig. 6 presents the schematic diagram of the microgrid [12].

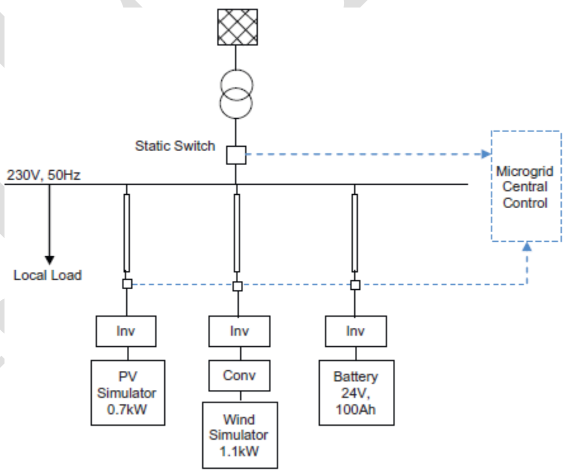

Fig.6 . Laboratory scale microgrid in Hong Kong [12]

MICROGRID IMPLEMENTATIONS IN KOREA

Korea's first pilot project is being developed by the Korean Energy Research Institute (KERI). The test system is very comprehensive as it includes several types of DGs such as PV simulator, fuel cells, and diesel generators, wind turbine simulator along with significant and non-significant loads. The network is equipped with storage and power quality devices. An energy management system is being implemented which even takes weather conditions into account and communicates with the components through a gateway. Being equipped with rich mixture of components, the KERI microgrid is aimed at testing and studying almost all aspects of microgrids. The whole project was implemented in two phases where in the first phase, the microgrid was kept as a 100kW class plant and in the second phase it was extended for further studies [13].

As shown in the circuit configuration the 100kW class microgrid system established in KERI consists of STS (static transfer switch) with IED (Intelligent Electronic Device), MMS (Microgrid Management System). The DGs includes photovoltaic, wind power, battery storage, and diesel engines. Additionally, there are some simulation equipments, such as RTDS (Real Time Digital Simulator), distribution line impedance simulator, line fault generator, various loads, and MG set for the simulation of wind power etc.

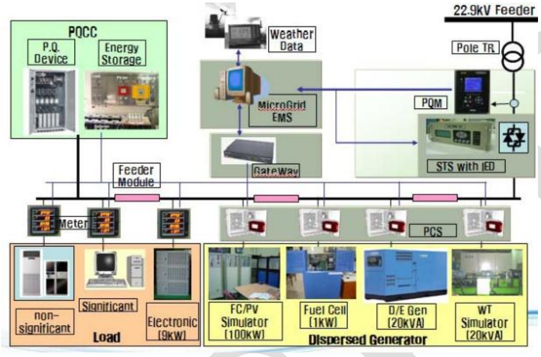

Fig 7 KERI microgrid pilot plant system configuration [13]

KERI has plan to extend the DG including 10kW Wind Turbine,30kW solar PV, 3kW thermoelectric generator, 1kW fuel cell and 30kVA super capacitor. KERI's next goal for microgrid system is to develop some technologies for low voltage power supply system and some types of commercial microgrid system. For the objective, KERI will establish 200kW class microgrid system like as Fig. 8 and it is moving on [14].

To mention the other budding projects the Korean Island Jeju is receiving increasing attention due to its immense potential for RE resources. The total wind power energy in Jeju was only 19 MW in 2006 and it has increased to 230 MW in 2009 whereas several fuel cell plants are either constructed or planned on the island [14]. Jeju Island and similar Korean islands are prime candidates for microgrid implementations in Korea in the future.

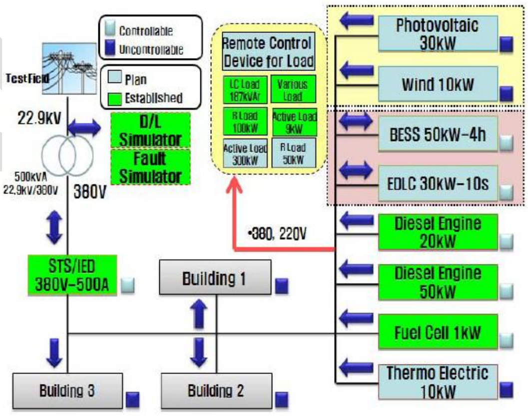

Fig. 8 KERI's future microgrid pilot plant system [14]

MICROGRID IMPLEMENTATION IN SOUTH-EAST ASIA

In Southeast Asia where millions of people have no access to electricity today, microgrids represent a hope full solution for providing a sustainable electricity

 Issue 4, Vol.3 (May 2014)
ISSN 2249-6149

supply especially to remote, off-grid rural areas. energy services companies (ESCOs) have successfully deployed a few microgrid systems in Southeast Asia for Malaysia, Singapore, Indonesia, Thailand and Vietnam.

In Malaysia:

Moved the furthest in microgrid deployment in Southeast Asia but mainly Greenfield projects with little to no cost recovery and subsisting on long term grants. Minimal collection of operational data and co-benefits tracking. Government initiated projects go through too many stakeholders, making it difficult to estimate the true costs of these projects [15].

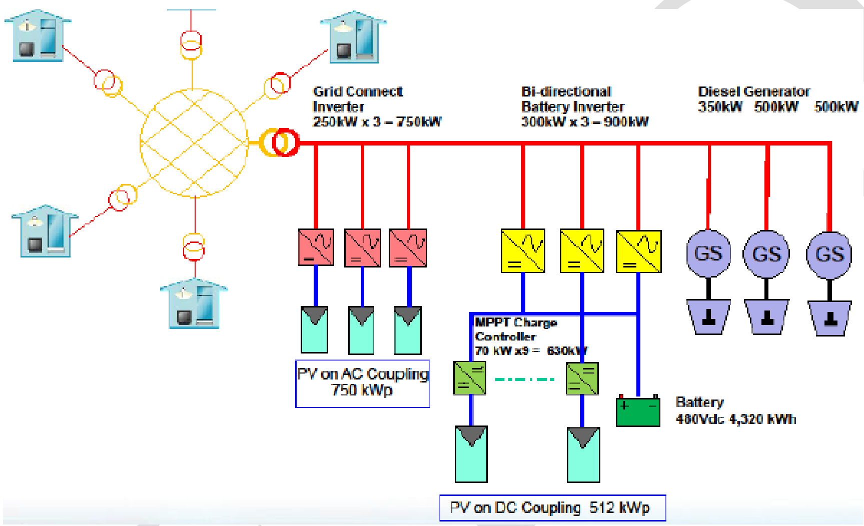

Fig 9 MW Scale System Tanjung Labian, Sabah (Malaysia)[15]

The Fig 9 shows a 4.2 MW system at Tanjung Labian, Sabah, Malaysia PV array: 1,262 kW ; •Inverter: 1,650 kW •Battery: 4,320 kWh / 480Vdc •Diesel generator of 1,350 kW.

In Singapore -

The Energy Studies Institute at National University of Singapore has under taken a project to evaluate if micro-grids can be an economically, socially and technically feasible option for electrification of the remaining un-electrified areas in Southeast Asia.

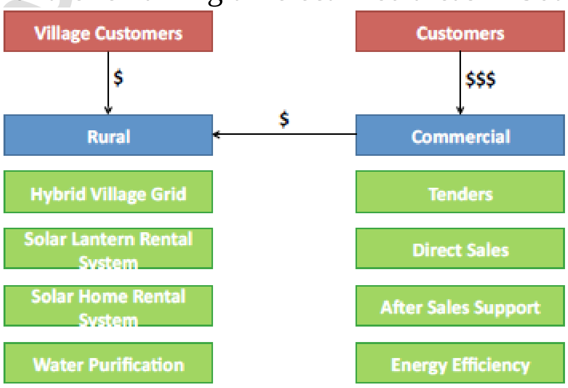

Figure 10: Sunlabob's Business Model [16]

Sunlabob Renewable Energy Off Grid, renewablr energy is a German-Lao commercial company providing energy services for rural remote areas currently out of the public grid's reach.

Government, World Bank, ADB, NGOs, Energy Service companies (ESCO) Village Committee Villagers Builds permanent electricity distribution infrastructure in the village, Continuously educates villagers on sustain abble use of electricity, Sets up and connects energy generation equipment, Sells electricity (kWh) to the village committee, Trains village technicians to operate and maintain the local grid. Figure 10 highlights the complementary nature of Sunlabob's commercial and rural businesses. Sunlabob runs a microgrid in Nam Ka province in Northern Laos and sells electricity to the villagers.

In Indonesia –

Government projects initiated through its ministries and agencies are eventually handed over to state utility, which is mandated to charge low electricity tarries to its customers which are usually below cost, leading to a long term loss profile for the utility which is unsustainable for mass microgrid deployment.

In Thailand –

Many existing microgrid installations are test beds set up by a university and the government with little private sector involvement since the 1990s. The reach of these projects is expected to remain small unless the government commits to go beyond the test bedding phase.

Selling microgrid systems directly to owners of Thailand's numerous remote and under electrified resorts could be a more at tractive option for ESCOs

In Vietnam –

Decentralized electricity distribution framework has upped rural electrification rates significantly in Vietnam. The same local competencies may be used to drive4 microgrid deployment in rural remote areas. However the obvious preference and plans for grid extension even to remote island and mountainous communities may rule out major interest were developed in simulated or controlled environment.

CONCLUSION

Microgrids are a future power system configuration providing clear economic and environmental benefits compared to expansion of our legacy modern power systems. It is clear that development of microgrid concepts and technologies requires considerable effort to resolve numerous economic, commercial, and technical challenges. As microgrid is being developed for operating in grid-connected mode under normal operation, justification for configuring a system for microgrid in developed countries is rather difficult as high degree of reliability is offered by power systems. The situation is more favorable to the remote islands of developing countries where the normal grid condition is weak and the power supply is less reliable.

In East Asia with successful implementations of microgrid projects at Japan there don't appear to be any major technical barriers to microgrid deployment. Besides Japan many other governments of the developing countries, remarkably China, Korea, Malaysia are now establishing microgrid research programs along with equipment vendors so the technical progress will inevitably accelerate. Extensive RD&D efforts are therefore in progress to provide efficient solutions and to demonstrate microgrid operating concepts in laboratories and in pilot installations. In South East Asia yet more research and implementation of microgrid is to be conducted in order to improve the maturity of microgrid technology.

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