MICRO GRID TECHNOLOGICAL ACTIVITIES ACROSS THE GLOBE : A REVIEW

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ABSTRACT

Innovations in technologies, economic benefits, quality requirements and environmental concerns are changing the face of the existing power system. Centralized generating facilities are giving way to smaller, more distributed generation partially due to the loss of traditional economies of scale. The need of an intelligent grid, better known as Micro grid at the distribution end, has been recognized to accommodate distributed energy resources (DERs) and renewable energy technologies on large scale. Micro grids 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. This paper highlights the concept, benefits and features of Micro Grids. The main technical challenges in the design, operation and control of Micro Grids are briefly outlined that must be overcome for their implementation effectively. The paper also presents a review the researches and activities of Micro Grid technology across the globe. It introduces the current Micro Grid research projects, especially in Europe, United State, Japan, Canada and India.

Keywords: *Distributed Energy Resources, Micro Grid Research Projects, Micro grid Issues &Challenges.*

1. INTRODUCTION

In this rapidly changing situation of the ways & means of electricity generation, issues related to high penetration of distributed generation within the generation & the distribution system require careful attention.

Up till now small generation units have been dispersed throughout power systems basically as uninterruptible power supplies. Generally these sources are not synchronized with the grid power supply though, but rather cut in when the primary supply is interrupted. Moreover they tend not to be interconnected with each other and typically each resource is dedicated to supply a predefined group of loads. With the role of distributed generation changing from backup to primary energy supply, more flexible connection strategies are required.

To realize the emerging potential of distributed generation a system approach is to be taken which views generation and associated loads as a subsystem or a "microgrid". The concept of Micro Grid has grown out of this desire for truly interconnected operation of distributed generation.

It is envisioned that this microgrid concept will prove to be an ideal solution to rural electrification besides its very well use in industrial parks, commercial and institutional campuses and many other situations requiring improved reliability and power quality. A micro grid enables small communities to take control of their energy use and reduce their carbon footprint through a new and innovative way of generating and managing electricity.

2. THE MICRO-GRID CONCEPT

A microgrid can be simply defined as an aggregation of electrical generation, storages and loads. The generators in the microgrid may be microturbines, fuel cells, reciprocating engines, or any of a number of alternate power sources. A microgrid may take the form of shopping center, industrial park or college campus. To the utility, a microgrid is an electrical load that can be controlled in magnitude. The load could be constant, or the load could increase at night when electricity is cheaper, or the load could be held at zero during times of system stress[6].

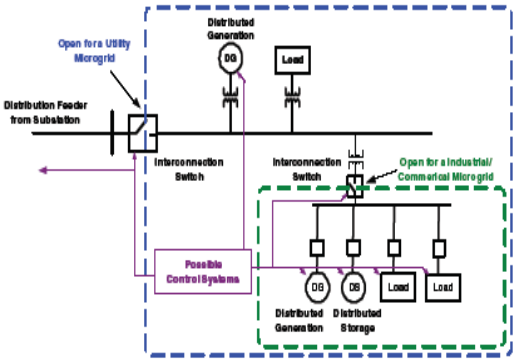
Distributed Generation DG refers to the numerous small, modular electricity generators, preferably new and renewable energy technologies which are located at LV lines, often close to the point of end use.

Concept of MicroGrid supersedes all the advantages of single source DG and hybrid DG. Moreover, it also includes all the advantages of networking, at mini scale.

A microgrid combined with power electronic interface is a completely self-sufficient network, with preferably autonomous control, communication and protection. It is capable of providing capacity support to the transmission grid while in grid-connected mode, and with capacity in excess of coincident peak demand.

So, the Micro grids comprise low voltage LV distribution systems with integration of Diverse Energy Resources DER such as photovoltaic, wind, bio-mass, bio fuel and fuel cell together with Distributed storage DS like flywheels, energy capacitors and batteries and Controllable Loads that behave as a coordinated entity networked by employing advanced power electronic conversion and control capabilities [8].

A schematic diagram is shown here for two types of microgrids: (i) Utility type microgrids which contain parts of the utility main grid and other one the (ii) industrial/commercial type microgrid which only include customer facilities [1].



There are many potential benefits to customers from the use of microgrids including improving reliability by providing power to the islanded portion of the electric power system (EPS) during a utility outage and resolving power-quality issues by reducing total harmonic distortion at the loads.

Distributed storage (DS) technologies are essentially used in microgrid applications as the renewable generation and loads of the microgrid cannot be exactly matched. Distributed storage provides a bridge in meeting the power and energy requirements of the microgrid. Distributed storage enhances microgrid systems overall performance in three ways. First, it stabilizes and permits DG units to run at a constant and stable output, despite load fluctuations. Second, it provides the ride through capability when there are dynamic variations of primary energy (such as those of sun, wind, and hydropower sources). Third, it permits DG to seamlessly operate as a dispatchable unit.

3. MICROGRID FEATURES

Micro grid is connected to the power delivery system at a point of common coupling PCC, thus appearing as a controllable single subsystem to the utility grid. The inter-connection switch is the point of connection between the microgrid and the rest of the distribution system.[14]

The microgrid concept enables high penetration of distributed generation without requiring re-design of the distribution system. A main feature of microgrid is to ensure stable operation during faults and various network disturbances. Autonomous operation is realized by opening the static switch, which disconnects the microgrid from the main grid. Distributed generations DG and corresponding loads can be autonomously separated from the distribution system to isolate the microgrid's load from the disturbance during faults. Also it will intentionally disconnect when the quality of power from the grid falls below certain standard. Once the microgrid is isolated from the main grid, the micro-sources supplies to the system are responsible for maintaining the voltage and frequency while sharing the power [8]

Microgrids desired features may be listed as follows:

- Accommodates a wide variety of generation options –distributed, intermittent and dispatch able.
- Empowers the consumer – interconnects with energy management systems in smart buildings to enable customers to manage their energy use and reduce their energy costs.
- plug and play functionality is the features for switching to suitable mode of operation either grid connected or islanded operation, provide voltage and frequency protection during islanded operation and capability to resynchronize safely connect microgrid to the grid .
- can independently operate without connecting to the main distribution grid during islanding mode, all loads have to be supplied and shared by distributed generations.
- Some micro-grids are equipped with thermal power plants capable of recovering the waste heat, which is an inherent by-product of fissile-based electricity generation called combined heat and power (CHP), these systems recycle the waste heat in form of cooling or heating in the immediate vicinity of the power plant.
- It services a variety of loads including residential, office, industrial parks, commercial, institutional campus.
- Provides power quality needed by 21st century users
- provide good solution to supply power in case of an emergency and power shortage during power interruption in the main grid,

- Self-healing – anticipates and instantly responds to system problems in order to avoid or mitigate power outages and power quality problems.
- Tolerant of attack – mitigates and stands resilient to physical and cyber attacks
- Fully enables competitive energy markets – real-time information, lower transaction costs, available to everyone
- Optimizes assets – uses IT and monitoring to continually optimize its capital assets while minimizing operations and maintenance costs – more throughput per investment.

4. MICRO GRID RESEARCH PROJECTS

A key feature of microgrids is that they can comprise of a variety of generation and loads. To accurately test these systems, a multifunction laboratory is needed that integrates generation, storage, and loads, as well as electrical and thermal capabilities. There are a number of active Micro Grid projects around the world involved with testing and evaluation of these advanced operating concepts for electrical distribution systems.

The Micro Grid research based on simulation study and hardware laboratory projects currently in progress to conduct field tests on Micro Grid applications are in Europe, the United State, Japan, Canada and India [2].

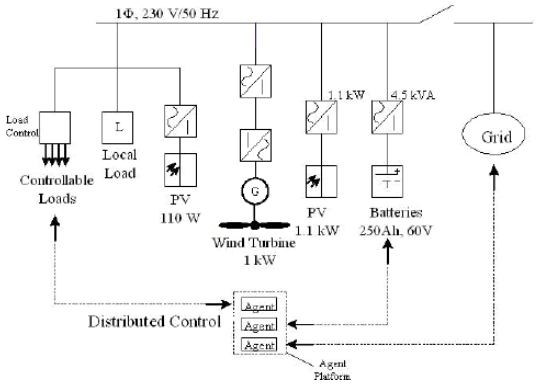
4.1 Microgrid project at the National Technical University of Athens (EU)

In the European Union (EU), the project was led by the National Technical University of Athens (NTUA) Greece together with research institutions and universities. The project was involved on simulation and demonstrates Micro Grid operation on laboratory scales.

The laboratory-scale microgrid system, installed at the National Technical University of Athens, comprises two PV generators, one wind turbine, a battery energy storage, controllable loads and a controlled interconnection to the local LV grid. The battery unit, the PV generators and the wind [13].

turbine are connected to the AC grid via fast-acting DC/AC power converters. The battery converter in particular is suitably controlled to permit the operation of the system either interconnected to the LV network (grid-tied), or in stand-alone (island) mode, with a seamless transfer from one mode to the other.

The configuration of the microgrid system installed at the National Technical University of Athens is shown in Fig.



The project was successfully completed providing several innovative technical solutions, which include the development of islanded and interconnected operating philosophies, local black-start strategies, and grounding and protection schemes, methods for quantification of reliability benefits.

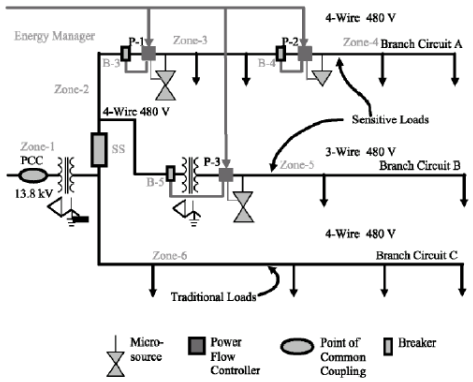
The other achievements of this project are to standardize the technical and commercial protocols and hardware to allow easy installation of distributed generation with plug and play capabilities. Other EU demonstration sites are taking place in Netherlands, Germany, Denmark and Spain.

4.2 Microgrid project CERTS by the US Department of Energy & California Energy Commission

The R&D activities in the United State on Micro Grids research programme was supported both by the US Department of Energy & California Energy Commission. The most well-known US Micro Grid R&D effort has been pursued under the Consortium for Electric Reliability Technology Solution CERTS which was established in 1999.

The CERTS Micro Grid is intended to separate from normal utility service during a disruption and continue to serve its critical internal loads until acceptable utility service is restored. Actually, the function provided by the CERTS Micro Grid is purposely to save cost and no single device is essential for operation, creating a robust system. The reliability of the CERTS Micro Grid has been well demonstrated in terms of simulation and the bench testing of a

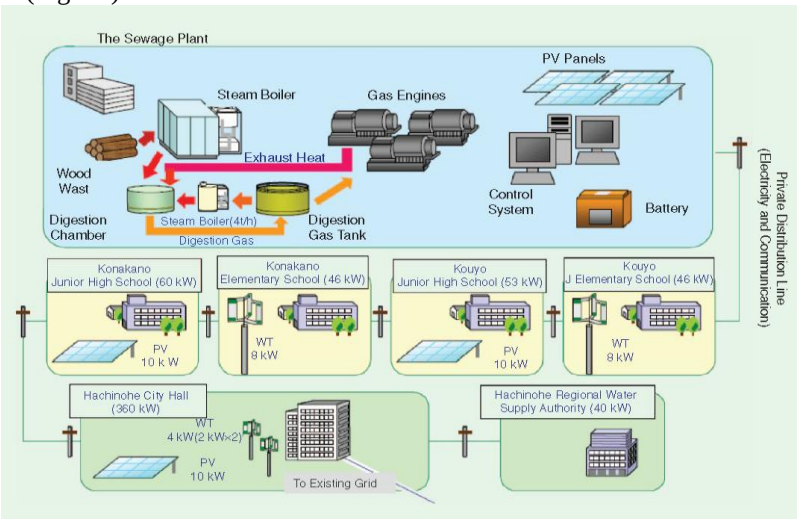
laboratory scale test system at the University of Wisconsin, Madison. Full-scale testing on the CERTS Micro Grid concept has been installed at the Dolan Technology Center in Columbus Ohio, which is operated by American Electric Power. [11].
Figure below illustrates the CERTS microgrid design with protected critical load circuits and unprotected traditional load circuits.



The CERTS Micro Grid has presents unique electrical analysis challenges such as contain three phase, single phase and variety of sources interconnected by power electronic devices employing different control approaches. The modeling approach enables analysis of a variety of issue such as prediction and evaluation of imbalance, asymmetries, generation-load control and dynamic voltage.

4.3 Microgrid project In Japan by New Energy and Industrial Technology Development Organization

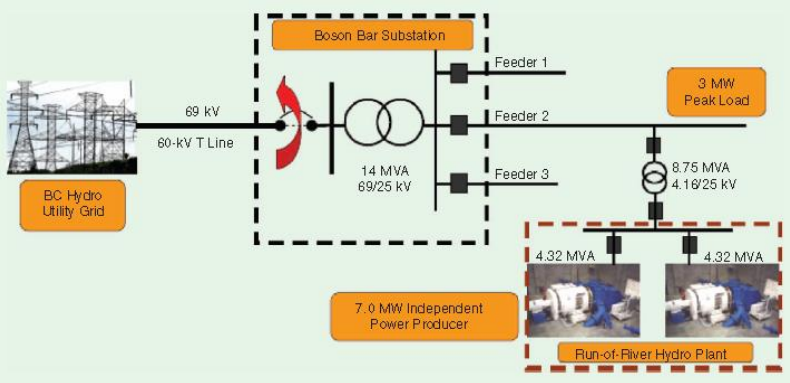
In Japan the New Energy and Industrial Technology Development Organization NEDO and the ministry of Economy, Trade and Industry started three demonstrations under its regional power grid with renewable energy resources project in 2003. Field tests were carried out by integrating new energy sources into a local distribution network. [12].
The Micro Grid projects were done in Hachinohe ,Aomori, Aichi and Kyoto. The main achievement is the development of an optimum operation and control system. Even though multiple field-test of Micro Grids are demonstrating the technical feasibility of Micro Grid, but clear economic and environmental benefits have not yet been demonstrated. Method for economic design and optimal operation of Micro Grid with renewable energy sources were proposed.
The Hachinohe project (Figure) features a microgrid system constructed using a private distribution line measuring more than 5 km. The private distribution line was constructed to transmit electricity primarily generatedby the gas engine system. Several PV systems and small wind turbines are also connected to the microgrid. At the sewage plant, three 170-kW gas engines and a 50-kW PV system have been installed. To support the creation of digestion gas by the sewage plant, a wood-waste steam boiler was also installed due to a shortage of thermal heat to safeguard the bacteria.
The Hachinohe project (Figure)



4.4 Micro Grid R&D activities at Boston Canada

The Micro Grid R&D activities in Canada focused on medium voltage and are mostly carried out in collaboration with the electric utility industry, manufacturers and other stakeholders in distributed energy resources integration and utilization. Micro Grid related R&D at the Canadian universities has primary focused on development of control and protection strategies for autonomous Micro Grid operation, Micro Grid islanding detection methods for parallel micro source in a Micro Grid and study the impact of high penetration of distributed generation in existing protection strategies. The Natural Resources Canada has also established collaborations with the utility industry to conduct field tests and experiments on applications of autonomous Micro Grid, grid-interfaced Micro Grid, planned Micro Grid islanding, and prototype testing and performance evaluation.

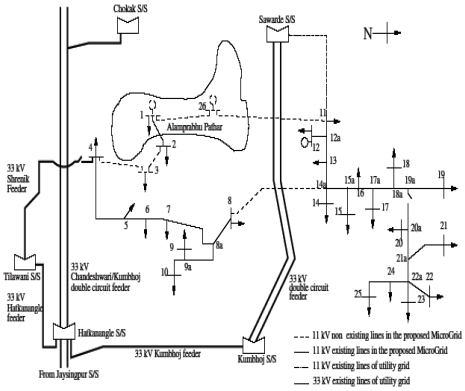
System configuration for the Boston Bar IPP and BC Hydro planned islanding site:



4.5 MicroGrid at Alamprabhu Pathar India by Maharashtra Energy Development Agency (MEDA)

In India for the execution of the MicroGrid project one of the sites selected is Alamprabhu Pathar a hilly area in Kolhapur district in the state of Maharashtra. The site is rich of identified energy resources, and is characterized by adequate load growth. Maharashtra Energy Development Agency (MEDA)has declared Alamprabhu Pathar as one of the wind sites,where good amount of wind power can be tapped off. Presence of sugar industries in close vicinity of Alamprabhu Pathar has made it possible to include bagasse based generators as one the constituents of the MicroGrid.

The 11 kV T&D main network around MicroGrid in Maharashtra India is shown in the Fig.



Around the Alamprabhu Pathar area, there exist a good amount of residential, agricultural, commercial as well as industrial consumers. Analysis shows that, 2400 kW of natural gas based generators, 500 kW of biomass based generators and 14250 kW of WTGs are to be installed to cater the load. Only one biomass based generator is required which is of 500 kW capacity. That means total 8 units of natural gas based generators, each of 300 kW capacity can be installed at various locations in the MicroGrid [14].

5. MICRO GRIDS ISSUES & CHALLENGES

Although clear benefits of micro grids are undisputable, there is considerable difficulty and key technical challenge to quantify them. Immense technical challenges associated with the operation and control of Micro Grids are summarized here [3]:

- 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
- Micro Grids 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.

6. OVERALL CONCLUSIONS

Micro grids 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. A micro grid enables small communities to take control of their energy use and reduce their carbon footprint through a new and innovative way of generating and managing electricity. The paper has accumulated issues and challenges associated with implementation of Micro grids and so the large scale deployment of the renewable energy technologies.

The state-of-the-art of issues of Micro Grid research projects, especially in Europe, United State, Japan, Canada and India has been presented. Although the the researches and activities of Micro Grids across the globe has not yet reached significant levels, however is experiencing a rapid growth.

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