Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 9; October, 2014 pp. 51-54

http://www.krishisanskriti.org/jbaer.html

Renewable Energy Integration & Topological Overview of Micro Grids

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Abstract: **Worldwide power grid evolution is taking place owing to the astonishing technological progressions, environmental imperatives and economic pressures. Distribution automation is captivating newer dimensions with introduction of active generation at the utilization end all over the world. Distributed Generation and Renewable power conversion systems close to the load are gradually relieving the network congestion on long-distance transmission lines besides supporting local power grids in the case of blackouts. The generation at the consumer end has noteworthy benefits but it can also destabilize the grid if not managed properly. The concept of Micro-Grid is proving to be an excellent way to incorporate distributed energy generation into the larger electrical distribution system. A Micro Grid must be capable of supplying both AC and DC loads as that is the mix we have in our domestic utilization. Over centuries AC power systems have been in use but with the inculcation of more DC generation type renewable energy sources and increased electronic DC load types the face of our local micro power system is also changing. In today's electricity grid the proportion of DC generation as well as DC type loads both have escalated. Thus depending on the diversity of load, the mix of primary energy sources, the geography and economics at work in particular areas micro grids are built with different capabilities, assets, and topologies. This paper presents various configurations according to which the distributed energy sources, energy storage devices and different types of AC-DC loads are interconnected in a Micro Grid.**

Keywords: Renewable Distributed Energy Sources, Micro-Grid Topologies, Hybrid AC-DC configuration.

1. INTRODUCTION

Micro Grids are portrayed as confined clusters of small generators, loads and storage devices. These autonomous networks connect as single entities to the main power distribution grid through a Point of Common Coupling (PCC) and a transformer. Micro Grids comprise a variety of technologies, Renewable sources, such as photovoltaic and wind generators are operated alongside traditional high-inertia synchronous generators; Distributed storage 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. The Micro Grid concept enables high penetration of Distributed Generation without requiring re-design or re-engineering of the distribution system itself. Power electronic interfaces and controls permit the aggregated units at each level to represent themselves to a higher level as a single self-controlled entity, DC or AC, load or generator. Fig.1. Illustrates a typical Micro Grid network with low voltage LV micro gird connected to medium voltage MV macro grid through PCC and transformer [1].

In the present power scenario we have ample types of generation resources and as many type of loads and on top of it as many types of power electronic converter topologies prevailing in the system.

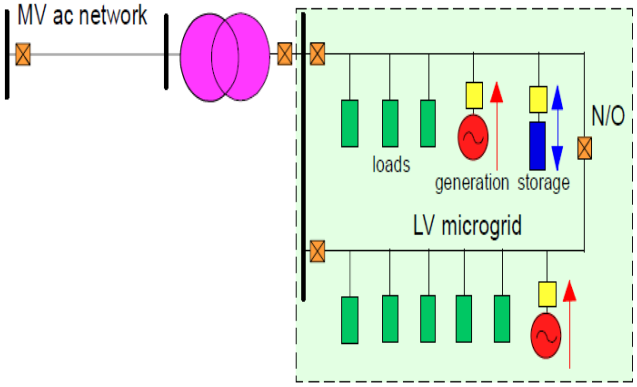

Fig.1 A typical Micro Grid [1].

This by itself gives a lot many types of interconnection methods making many network topologies possible. Considering such multiple factors many permutations and combinations are feasible for Micro Grid configurations few of which have been presented in this endeavor. Since the Micro Grid concept is very versatile, the experiment conditions and the objectives have a very wide span. Different technologies, topologies and operating modalities have been planned, employed and executed for different purposes as per the local requisites. In this paper we shall attempt to appraise various Micro Grid topologies, set up specifications, and operational configurations [2].

2. OPERATING MODES OF A MICRO GRID

A Micro grid can be a single or a three phase system and it may be connected to low voltage or medium power distribution networks. Its configuration can be a DC, AC or hybrid AC-DC or even a high frequency AC grid. Micro Grid is connected to the main distribution system by the Point of Common Coupling (PCC) and can operate in two modes either grid connected or islanded operation mode. For each operating mode operational requirements are different and distinct control schemes are obligatory.

The leading edge feature of a Micro Grid is its ability to operate autonomously when there is a power outage in the main grid. This operation mode is called islanded operation since the Micro Grid disconnects from the grid and becomes an island continue supplying to local loads with local generators. A Micro Grid disconnects automatically from the main distribution system and changes to islanded operation when a fault or maintenance occurs in the main grid or the power quality of the grid falls below a required standard and has ability to reconnect to the grid once they are resolved. This way Micro Grids not only help in providing uninterrupted service but also contribute to the maintaining service quality [3].

3. MICRO GRID SYSTEM TYPE AC V/S DC

Over centuries the conventional electrical system in use have been the AC power systems due to its efficient transmission capacity over long distances and different voltage levels transformability. Newly as more renewable power conversion systems are connected in ac distribution systems locally long distance transmission necessity no longer exists. While until now homes have been usually seen to require an AC supply for inherently high power devices like washing machines, mixer-grinder, geysers etc. there are a surprising number of areas like lighting, electronic equipment internet, intercom, telephone, and television, electric vehicle etc. that need DC supply.

Lighting is widely considered to account for around 20% of global electricity consumption and a recent report from the International Energy Agency gives an estimate that up to 15% of domestic energy is consumed through electronic gadgets. Further more commercial complexes, offices, hotels etc. are the environments which have major lighting and electronic load only. LEDs are rising as a preferred option for high efficiency lighting, and they run on DC power. Similarly, most gadgets mobile, computers and consumer electronics operate on DC power, so these two sectors alone add significant and increasing global consumption of electricity by DC devices [4].

So with renewable technologies such as solar photo-voltaic, fuel cells and wind power prevalent at a household and commercial complex level it appears that DC micro-grids could be a more efficient and cheaper alternative. In such cases a DC Micro Grid could be the sole power provider. The elimination of inverter cost, simplified installation and reduced fuel costs yielded by a DC Micro Grid system potentially make it cost effective to operate independently of the electricity grid and conventional mains-power generators.

4. MICRO GRID TOPOLOGIES

The structure or topology of a Micro Grid can vary considerably as per the type of load and local available micro sources generation characteristics. Broadly various configurations techniques of the distributed energy sources, energy storage devices and different types of loads in a Micro Grid can be categorized into the following alternative:

- AC line frequency bus interconnection
- DC bus interconnection
- Hybrid AC-DC bus interconnection

4.1 AC Line Frequency Bus Interconnection

Initially AC Micro Grid configurations have been proposed and the generated DC power from PV panel, Fuel cell etc. are also converted into AC at line frequency 50 Hz in order to connect to an ac grids. In an ac grid set in booster dc/dc and ac/ac converters are required for various home and office facilities to supply different ac voltages. Figure 2 shows an AC Micro Grid system.

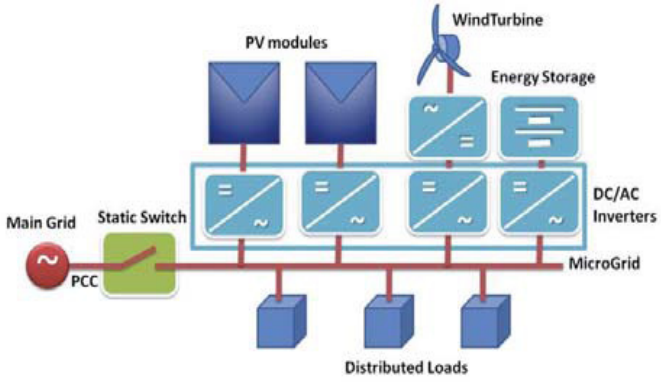

Fig.2. AC Micro Grid system [5].

4.2 DC Bus Interconnection

Recently DC grids are being preferred as most of the DERs generate DC power and the DC distribution system has no power quality problems. Due to the development and deployment of renewable dc power sources and their inherent advantage for dc loads in commercial, industrial and residential applications research on DC micro grid system is getting importance. The dc Micro Grid has been proposed to incorporate various distributed generators and ac sources have to be converted into dc before connected to a dc grid and dc/ac inverters are required for conventional ac loads. The DC bus is

the most simple and common interconnection bus. This system has no frequency and phase control requirements, high efficiency and high reliability compared to the AC interconnection bus. Moreover, it has low distribution and transmission losses, low cost, dispenses the use of transformers, leading to volume and cost reduction [6].

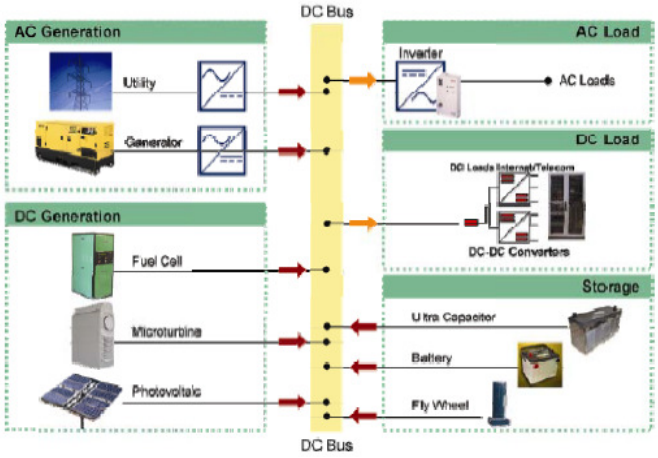

Fig.3. DC Micro Grid system [7].

But most of the loads are operated in AC system; hence, DC distribution system may not be popular yet; multiple reverse conversions required in individual ac or dc grids may add additional loss to the system operation. Figure 3 shows a DC Micro Grid system.

4.3 Hybrid AC-DC Bus Interconnection

As both dc and ac micro-sources and load components usually coexist in one system therefore they can form a hybrid Micro Grid. A typical ac-dc hybrid Micro Grid consists of three main parts: (i) ac Micro Grid, (ii) dc Micro Grid and (iii) power electronics interfaces and transformer galvanic isolation between ac and dc buses [8].

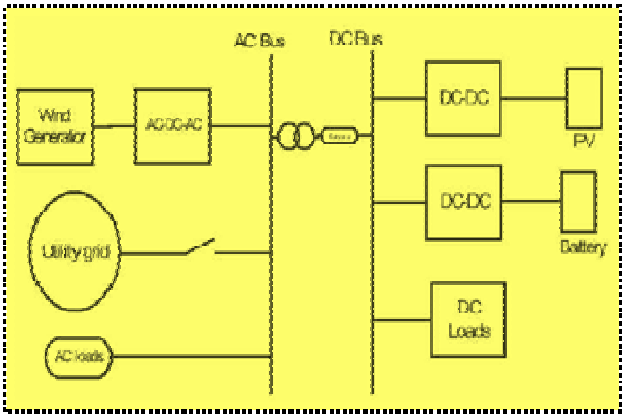

Fig. 4 Hybrid micro power system [9]

Fig.4 shows a hybrid Micro Grid system configuration, an effective way of utilizing primary energy sources where various ac and dc sources and loads are connected to the corresponding dc and ac networks. The AC and DC buses are coupled through a three phase transformer and a main bidirectional power flow converter to exchange power between DC and AC sides. The transformer helps to step up the AC voltage of the main converter to utility voltage level and to isolate AC and DC grids.

Although the hybrid grid can reduce the processes of DC/AC and AC/DC conversions in an individual AC or DC grid, there are lots of practical problems for the implementation of the hybrid grid based on the current AC dominated infrastructure. The hybrid grid may be feasible for small isolated industrial plants with both PV systems and wind turbine generator as the major power supply [10].

5. HYBRID MICRO GRID EXTENDED TO EXAMPLE SMART GRID TESTING AT NREL

In the past decade the majority of micro-grids had been only as pilot projects or research-related experiments.

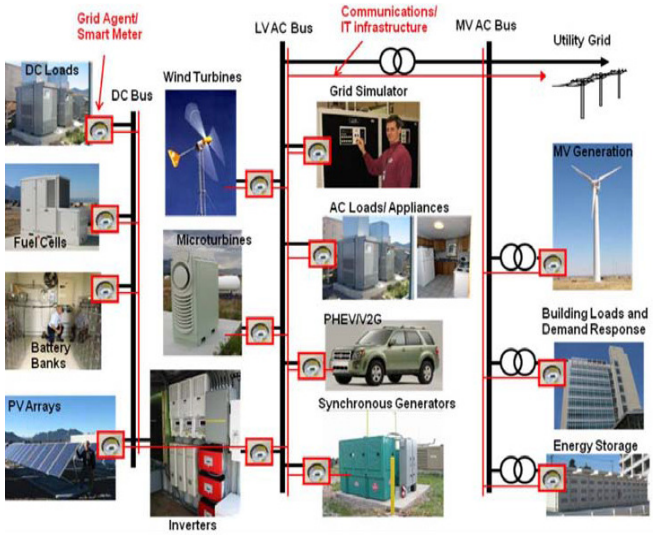

Fig.5. NREL Hybrid AC-DC Micro Grid [11]

Recent years have indicated a shift as some of the first commercial-scale Micro Grid projects reached noticeable milestones very fast specially in the developed countries. The budge from pilot corroboration projects to fully commercial projects is accelerating with the passable adoption of the IEEE islanding standards for micro-grids. At the National Renewable Energy Laboratory (NREL) U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, smart grid interconnection and interoperability testing activities are being extended beyond the initial undertakings as shown in the Figure 5**.**

6. HIERARCHICAL INTEGRATION OF DC AND AC MICRO GRIDS

In this topology framework, a large set of DER units are integrated into a three-level hierarchy through advanced power electronics and appropriate controls: a set of basic DER units are first integrated to a DC bus link through DC/DC or AC/DC converters; a collection DC buses are then integrated into an AC bus link through inverters; and a range of AC buses are finally integrated into a Micro Grid. Micro grids can be directly interconnected with the power distribution system at a point of common coupling (PCC). DC loads such as those in residential applications can be directly connected to the local DC buses, while AC loads are connected to the AC buses through feeders. This hierarchy-based approach provides more flexibility and reliability for DER integration.

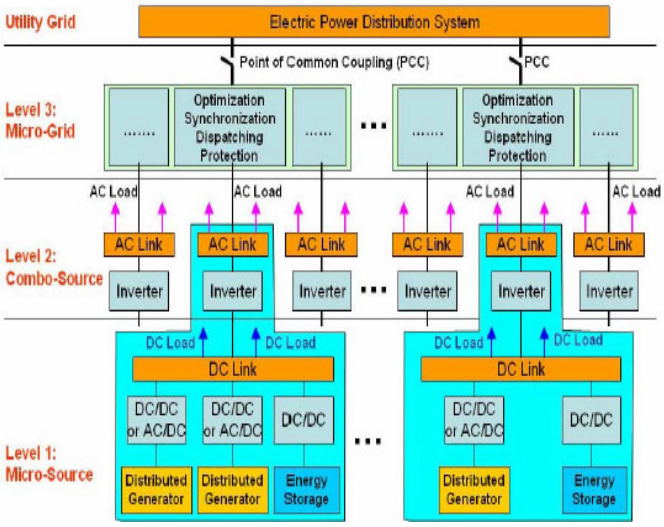

Fig. 6 A Hierarchical Frameworks for Micro Grid [12]

7. CONCLUSION

Micro Grids are establishing to be the best solution to exploit the full renewable energy potential and allow a well-planned plug-and-play integration of Distributed Generation. The degree of their interplay and incorporation will be a function of rapidly rising smart grid capabilities and requirements. There is no particularly accepted benchmark test system for Micro Grids; as per the local necessitate different systems employ diverse Micro Grid topologies. The efficiency of the total system depends on the diminution of conversion losses and the increase for an extra DC link. The hybrid grid can provide a reliable, high quality and more efficient power to consumer. The hybrid grid may be feasible only for small isolated industrial plants with both PV systems and wind turbine generator as the major power supply. Although the hybrid grid can lessen the processes of DC/AC and AC/DC conversions in an individual AC or DC grid, there are many practical problems for the implementation of the hybrid grid based on the current AC dominated infrastructure.

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