Overview: Simulation Analysis of Low Voltage DC Micro Grid – An Investigation of Load Sharing by using MATLAB

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Abstract— The micro grid concept has the potential to solve major problems arising from large penetration of distributed generation in distribution systems. The micro grid was designed to operate connected to the main network. The micro grid operated appropriately for different steady state operating conditions. A proper control strategy should be implemented for a successful operation of a micro grid. This paper presents a performance study of a dc micro-grid when it is used a voltage droop technique to regulated the grid voltage and to control the load sharing between different sources like Photovoltaic cell , Fuel Cell, Batteries, etc. Some aspects about centralized (master-slave) and decentralized (voltage droop) control strategies are presented. In this paper, the work done in the field of Micro Grid has been reviewed.

Key words: DC Micro Grid, Voltage Droop Control, Power Electronics Devices, Renewable Energy Resources

I. INTRODUCTION

Micro-grid (μG) is a electrical network comprising loads, micro-sources (μS) and communication & automation systems. These μS, also called distributed sources (DS), increase the offer of energy, the reliability and the efficiency of electrical power systems since they are able to operate close to loads and connected to or not to another electric power network [1].

A small scale system and located near the consumer is called the Micro-Grid (MG) system. The interconnection of small generation to low voltage distribution systems can be termed as the Micro Grid. Micro Grids can be operated with and without a connection to the main power network. Small Capacity Hydro Units, Ocean Energy and Biogas Plants ,wind, diesel-generation, PV, energy storage etc are the various energy resources in MG for electrification of areas mainly rural areas where there is no possible access to grid electricity due to poor access of remote areas to technical skills. The micro grid has to be designed in such a manner so that there is ease in installation, commissioning, operation and maintenances. Micro grids can be defined as low voltage networks with micro-generation sources (micro sources), together with local storage devices and interconnected loads. Nowadays, Loads like lighting systems and electronic equipments (e.g. Computers and peripherals communication devices, tv sets among others) are responsible for about 35 % of the electricity consumption in residential and commercial applications [3].

Micro grid systems are usually small scale power supply networks with total installed capacities around a few hundred kilowatts. The aim of designing such systems is to provide uninterruptible high quality power to sensitive loads in a certain area. The feature that makes micro grid a unique power system is that, although it operates most of the time in parallel with the grid, it can be automatically transferred to island mode whenever its control system detects a fault or disturbance in power quality from the upstream network. When the fault is cleared or the disturbance disappears, the micro grid can be resynchronized with the main network, after assuring that its sensitive loads are continuously secured.

Micro grid is developed in places like shopping center, parks, college campus, industries, hospitals, buildings, etc. The application of individual distributed energy resources such as micro-generation can cause problem such as voltage rise, potential to exceed thermal limits of certain lines and transformers and have high capital cost [11]. Micro grid can be the best solution for these problems.

II. MICROGRID TOPOLOGY

Due to the ever-increasing demand for high-quality and reliable electric power, the concept of distributed generation and energy storage has attracted widespread attention in recent years. Distributed generation and storage systems consist of relatively small-scale generation and energy storage devices that are interfaced with low- or medium-voltage distribution networks through power converters and can offset the local power consumption, or even export power to the upstream network if their generation surpasses the local consumption. An upcoming philosophy of operation which is expected to enhance the utilization of distributed generation and energy storage is known as the micro grid concept.

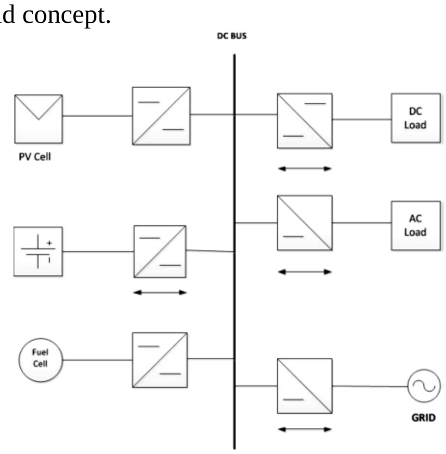

Fig. 1: Generic topology of a dc micro grid

Figure. 1 shows an example of a generic dc micro grid with micro-sources, energy storage systems, dc and ac loads. Static converters connect all devices to the dc grid. A dc-ac converter is used as interface between the dc μG and the ac electric distribution network. This converter is blocked in the case of islanded operation of the dc micro-grid.

In this scenario, an important issue related to the operation of dc micro-grids is the dc bus voltage regulation.

Two types of voltage control are commonly used in the literature: master-slave and voltage droop. The master-slave method depends on the communication between the interface converters. The master converter controls the voltage of the dc bus and sends reference signals to other converters. In the method of volt-age droop, the dc bus voltage is measured at the points of coupling of the converters and it is used to calculate the amount of energy that each load or source will consume or supply.

III. CONTROL OF PARALLELED CONVERTERS

The paralleling of power sources in micro grid applications through power electronics modules offers a number of advantages over the utilization of a single high power converter [2]. Two different methods can be used to control paralleled converters on a micro-grid: master-slave and voltage droop [6]. In this section some particularities of each method will be presented.

A. Master-Slave Control

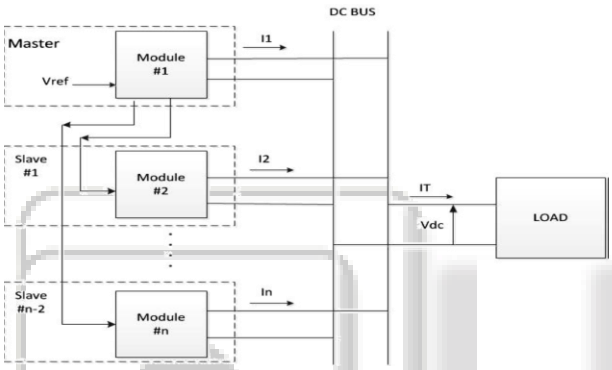

Fig. 2: Schematic diagram of Master Slave Control

Figure 2 shows the block diagram of the master-slave control scheme. In this figure, each block is composed by a dc source, a static converter and its controller. The first block, the master module, controls the grid dc bus voltage while the other blocks, the slaves, are current controlled. Despite of the fully controllable load sharing [9], this control scheme has the disadvantage of needing a fast communication channel since the reference currents for slave converters are provided by the master block. The loss of the communication link or mal-functioning of the master block can shut down the whole system [7] and [8]. Thus, to avoid or reduce the probability of failure, this system should be design with some redundancy.

B. Voltage Droop Control

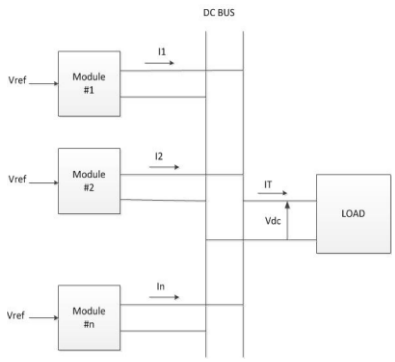

Fig. 3: Voltage Droop Control

Figure 3 shows the block diagram of the voltage droop control scheme. Each droop controller emulates an impedance behavior reducing the converter output voltage with the increase of the supplied current. This strategy promotes the current sharing between paralleled converters connected in the dc micro grid without the need of a central control.

Such method is able to avoid critical communication links. The absence of critical communications between the modules improves the reliability without restricting the physical location of the modules. The droop method is based on a well-known concept in large-scale power systems, which consists of drooping the frequency of the AC generator when its output power increases [4]. In common voltage droop control, the DC bus voltage decreases linearly as the DC side current, or in some cases power, of the converter increases, in order to give stable operation.[10] .The droop method achieves higher reliability and flexibility in the physical location of the modules since it only uses local power measurement.

IV. POWER FLOW

The power flow of the components in the proposed DC micro-grid is shown in Figure. 4. The sum of the output power of the photovoltaic array, the wind power generator and the fuel cells is defined as PDG in equation (1).

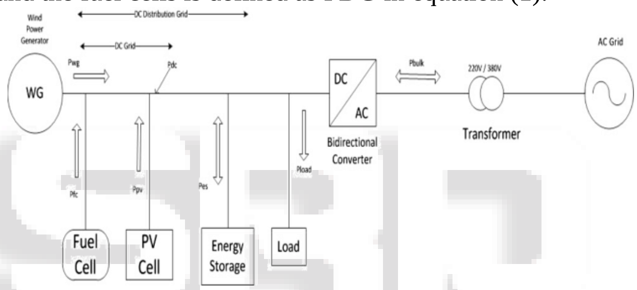

Fig.4 Power Flow in dc micro-grid

$$P_{DG} = P_{PV} + P_{WT} + P_{FC} \quad \text{………..} (1)$$

The DGs supply unidirectional power to the DC micro-grid and play a role as the main energy source. Since energy storage elements control the power balance of a DC micro-grid by charge and discharge, the power flow is bidirectional and the reference power for the elements is in equation (2). When the energy storage elements reach the state of full charge or discharge, the excessive power is supplied to or obtained from the AC grid, as shown in equation (3). The load demands unidirectional power from the micro-grid. According to a varying load demand, the energy storage element realizes a power balance, and thus it makes a continuous high-quality power supply to the load possible.

$$P_{ES}=P_{DG}-P_{LOAD} \quad \text{…………} (2)$$

$$P_{BULK}=P_{DG}-P_{ES}-P_{LOAD} \quad \text{..............} (3)$$

The loads are assumed to demand unidirectional power from the micro grid. According to a varying local demand, the distributed storage systems realize a power balance, and thus make a continuous high-quality power supply to the load possible [9]. In a case of power shortage that can occur when utility grid is not available, non-critical loads can be disconnected from the micro grid. The power management method is analyzed in the both grid tied mode and in the islanded mode. A grid-tied converter has control over the DC grid voltage in the grid-tied mode and energy storage elements have control in the islanded mode. A super-capacitor and a battery ensure a high quality power supply to the load in both modes.[5]

V. MICROGRID OPERATION MODES

A micro grid is connected into the utility grid through a bidirectional power converter that continuously monitors both sides and manages power flow between them. If there is a fault in the utility grid, the power converter will disconnect the micro grid from the grid, creating an islanded energy system. The micro grid can continue to operate in the islanded mode, that is primarily intended to enhance system reliability and service continuity, and it is typically unplanned. However, it can also be introduced intentionally for maintenance purposes through the main switch. In some cases, islanded operation is the only mode of operation, e.g. in off-grid remote electrification system. Concluding, there are two operation modes for a micro grid: (i) grid-connected, and (ii) islanded mode.

A. *Grid-Connected Mode*

In the grid-connected operation mode, the grid-tied power converter has control over the DC link voltage level. If the output sum of the power of the distributed generation systems is sufficient to charge the storage devices, any excessive power is supplied to the utility grid. If the sum of the power of the distributed generation and storage systems is deficient with respect to the load demand, the required power is supplied from the utility grid. In the grid-connected mode, power management is performed in a complementary manner between storage devices and as a result a DC micro grid can operate safely and efficiently.

B. *Islanded mode*

When a DC micro grid must be separated from the utility grid and switch to the islanded mode, the grid-tied power converter releases control of the DC link voltage level, and one of the converters in the micro grid must take over that control. Since each converter of distributed generation sources is used for optimal control of its belonging source, only the converters of the energy storage elements are free to regulate the DC link voltage level. During the islanded mode, the battery plays the main role in regulating the DC link voltage level, and the super capacitor plays a secondary role in responding of the sudden power requirement as an auxiliary source/sag, i.e. for peak shaving during transients.

VI. CONCLUSION

After going through this review based on the given title, it has been concluded that issues of unreliable power quality, increased focus on renewable energy, need for rural electrification, and focus on higher efficiency have resulted in more emphasis on developing micro grid infrastructure. The ability of MG to island generation and loads together has a potential to provide a higher local reliability than that provided by the power system. Regarding distributed generation, the distribution systems have undergone the changes over the recent decades, along with the fact that many of these sources can be connected to form independent micro grids, have challenged this protection perspective. In this paper describe operation modes and control methods of a DC micro-grid. A micro-grid can operate in a grid connected mode or in an islanded operation mode.. The main difference between aforementioned control methods is that droop control methods do not require fast communication between components (i.e. generation sources and storage devices), thus improving system reliability and flexibility at the cost of the DC link voltage level stability.

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