A review on Microgrid operation and control

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Abstract: Grid means the interconnection of different energy sources, operating at same voltage with proper synchronization. The micro-grid is actually composition of low voltage distributed generators with proper controlling scheme. This paper mainly describes about different models of micro-grid and its contribution to the distribution system under different operating conditions (i.e. grid connected mode, isolating mode and disconnected mode) .The different controlling techniques used by the micro-generation systems for stable power distribution are also explained using closed loop control system

Index Terms **- Micro-grid, Distributed generator, operation, control, grid dependent, autonomous mode**

I. INTRODUCTION

Traditionally Power system was defined as combination of generation, transmission and distribution system. But the definition of modern power system has changed .The improvement in power quality has encouraged private power companies to participate in the distribution sector. The non centralized control of power distribution is called as deregulation of electricity. Earlier generating units were controlled by the government bodies and most of them were thermal based power units but nowadays private industries have started developing power not only for the manufacturing process but also for the domestic load supply. Such power generation has low rating and mainly used at distribution side for low voltage consumers. This kind of small generating unit of few Megawatt capacities is called as Distributing generator or distributed energy source. The cluster of multiple generating units integrated or islanded with the grid is called as micro-grid. Company like TATA power solar has implemented several micro-grids which are based on PV panel. This solar project has been successfully installed in Chhattisgarh region which has capacity of 14000 kWh and covers over 400 villages where electricity was not available [1].Similarly there is another project installed by ABB India, where Micro- grid has been installed with energy storage. This innovative micro-grid has been inaugurated at Vadodora manufacturing campus [2].

There are several models of micro-grid. The Distributed energy source or energy storage unit present in any micro-grid, supplies power from grid to the utility. The interconnection of micro unit to the distribution grid follows certain parameters. The operation of micro-grid is mainly governed by IEEE 1547[3].This standard provides essential points relevant to the performance, operation, control, testing, safety and maintenance. This standard is applicable for all type of distributed energy sources, with aggregate capacity less than equal to 10 MVA. The design consideration includes general operating condition, abnormal condition, islanded or standalone operation with information exchange interface.

II. ARCHITECTURE

A. Design consideration of Micro-grid

The structures of all micro-grids are not-identical. The various models of micro-grid are designed on the basis of following parameters-

- Nature of Source- It depends on the behavior of the supply, whether it provides alternating quantity i.e.AC supply or direct quantity i.e. DC supply. Recently using convertors hybrid supply (i.e. DC to AC supply) is possible.
- Types of Source-There are various sources of energy, but mainly there are sub categorized as renewable and non-renewable source of energy.
- Mode of Operation- The micro-grid mainly works in two different modes i.e. Either Grid connected mode or isolated (Islanded) mode.
- Types of consumer- There are three types of consumer i.e. residential, commercial and industrial. The voltage rating for industrial load is more than other types of consumers.
- Based on controlling scheme- The micro-units of a grid could be central controlled or local controlled. The communication interface is different in both conditions.

Several power companies of different countries have described the paradigm of micro-grid with its specification. The research works on micro-grids are mostly based on test bed or simulation. BC hydro Boston bar, a Canadian power company has developed a micro-grid which consists of two 4.32 MVA run-of- hydro power generators, connected with 69 kV feeder [4].University of Wisconsin, United states has implanted micro-grid based on internal combustion engine with battery backup system[6]. Kythnos island micro-grid, Greece has 10 kW generating capacity, based on PV with 53kWh battery bank and 5kW Diesel generator set [5].University of Manchester has developed a micro-grid, which contains synchronous generator coupled with induction motor and flywheel system. The kinetic energy from flywheel is converted into electrical energy [6].Aichi micro-grid project, Japan has developed micro-grid for airport in which different type of fuel cells and PVs are integrated to supply 6.6kV grid. The alternating supply is available due to the inverters used for each unit [7].A test micro-grid system at the Institute of Engineering and Technology-India has introduced PSO based inverter used for back-up power [6].

As per the report of EPRI, micro-grids are classified on the basis of their area of application [8]. The can be categorized as

- Commercial/ Industrial micro-grid- These are used for reducing the demand and the cost of power and it helps to provide continuous back up supply for critical loads like data centers.
- Community/Utility micros-grids- These types of micro-grids are used for reliability improvement of critical infrastructure .These are fit as per energy and emission policy.
- University campus micro-grids- Every campus has its own DG system. The power requirement for different labs with back up energy system increases the reliability.

- Public institutional micro-grids- Public places like police station, hospital, fire station etc. require uninterrupted power. These types of micro-grids are efficient for such areas.
- Military micro-grids-These micro-grids are used for army purposes. The communication system, cyber security and lighting system in army camps gets power from such micro-grid. It can be used fixed base or operational base.
- Rural micro-grids- These are remote micro-grids independent of main grid. Mainly diesel generators or renewable energy are used for production of electricity.

B. Typical structure of Micro-grid

Different models of micro grid are described in Section-A. A typical micro grid includes different units i.e. generation unit, energy storage unit, power converter unit, switching unit, communication and control unit. The power supply from synchronous machine is AC in nature but power supplies from PV, battery, fuel cell etc. are DC in nature. The hybrid type of micro-grid includes AC as well as DC sources. Batteries are used for energy storage and also for power supply during load shedding. DC to AC convertor is used for all type of DC sources. The main problem occurs when new DG is introduced to parallel connected generating units. The units connected must satisfy all the conditions of parallel operation. Any abnormal behavior in parameters could cause transient situation, hence protection and switching units must response quickly for safe operation. The interconnection of micro grid takes place at point of common coupling (PCC).This is the point which differentiates utility side and generation side in distribution network as shown in fig 1. The generating units presented in this paper are commonly used power sources. It is not restricted that power source must be only from synchronous machine or alternator. Hybrid source of energy i.e. utilization of energy from both non-conventional and conventional sources are much appreciated. The reduction of carbon emission has become a major challenge; therefore renewable sources are highly promoted for power generation. The interconnection of renewable source like PV often need power conditioner for better quality.

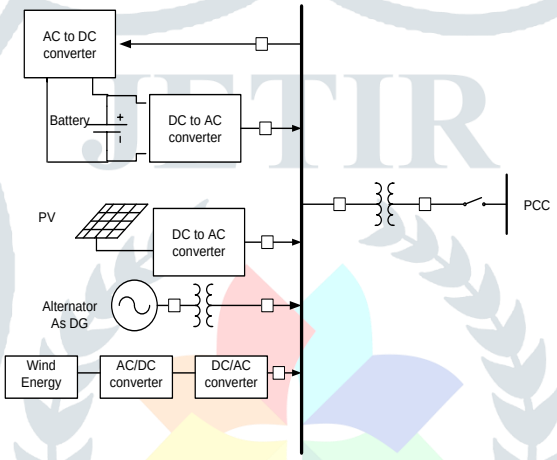

Fig 1: Typical structure of hybrid type micro-grid with PCC

III. OPERATION

The micro-grid is often described as cluster of Distributed generators but the operation of micro-grid is little different from the DG. In DG we choose suitable location and size for optimal power flow but in case of micro-grids PCC is the point where power is injected to the distribution side. The main intention of distributed power supply is to maintain power quality in distribution network. The system would be reliable when distributed source acts as backup power source during outages. As per different working scenario the modes of operation can be classified into following categories [9].

a) Grid connected mode
b) Isolating mode
c) Disconnected mode

a. Grid connected mode

In this mode, power supply from main substation is available and the micro-grid works parallel with the main source. The parallel generators must have same rated voltage, same frequency and proper phase sequence. In this case micro-grid operates as single generating unit but sometimes micro-grid itself acts like a load when the energy storage units utilize power from the grid.

b. Isolating mode

In this mode, power supply is provided only from the micro-grid. This is often called as islanding. This situation occurs in the system when outage takes place due to fault in the main substation or due to maintenance work in the main grid.

c. Disconnected mode

In this mode, micro-grid is disconnected from the PCC. This situation occurs when the power demand is quite less. Sometimes it has been observed that micro-grid cause over current, which is undesirable .Even in that situation micro-grid, is disconnected from the main grid.

The main objective for any suitable operation mode is power stability. Several researches have been done for optimum micro-grid design. The switching control and the protection scheme are crucial for safe operation. Different studies have been made on micro-grid operation. The switching operation in distribution network often cause transient in the circuit. An analysis based on preplan switching event and fault event explains that transient occurs when conventional rotating synchronous machine corporate with electronic power converter. (DC to AC supply) .The abnormal behavior of parameter in short interval of time develops a faulty

situation in the grid. This study has included all type of unsymmetrical faults[10].A study based on optimal protection scheme states that selection of fault current limiter (FCL) reactor can reduce the fault current in grid connected and islanded type of micro-grid system. In this study problem has been formulated using constrained non-linear programming (NLP) and Genetic Algorithm (GA) is used to optimize the equation [11].One more study related to the design of micro-grid has formulated different controllers, filters and power sharing coefficient .The effectiveness is observed under different disturbances and load conditions. This research is based on VSI controlled micro-grid, where the droop of frequency w.r.t active power and the deviation in voltage profile w.r.t reactive power have been formulated [12]. The droop characteristics occurs when load site increases and frequency falls. The reactive power present in the system maintains voltage profile. These parameters are controlled using different schemes that are described in the next section.

IV. CONTROL

The micro-grid is often described as a cluster of Distributed generators. Addition or isolation of generating unit changes the basic parameters i.e. voltage, current, frequency and power. This happens in both operating modes i.e. grid-connected mode and isolating mode. The mismatching of frequency causes instability, which could be observed in the voltage waveform. The switching phenomenon occurs during isolation or introduction of new generating unit causes surge in the line. The proper control of micro-grid is necessary for stable and economical operation. The following objectives must satisfy while controlling [13].

- Voltage and frequency regulation.
- Proper load distribution and DG coordination.
- Synchronization with main grid.
- Load flow control in micro-grid and main grid.
- Protection during transient and abnormal faulty conditions.

The controlling mechanism includes hierarchical structure and includes different level of control. The control strategy is divided into three levels primary, secondary and tertiary. The process starts from primary control which ensures voltage stability, frequency stability and DG control. The secondary control includes compensation of voltage and frequency affected by the primary controls and the tertiary control involves the overall load flow control between micro-grid and main-grid. The overall controlling process includes closed loop systems.

A Control strategy

The primary control strategy can be further subcategorizes as PQ control, droop control, voltage/ frequency control and current control techniques.

PQ control – This type of controlling scheme is applicable for inverter type of distributed source .The output power is controlled by the adjusting suitable firing angle. The overall operation is closed loop control system where park's transformation is applied for SPWM control [13, 16].

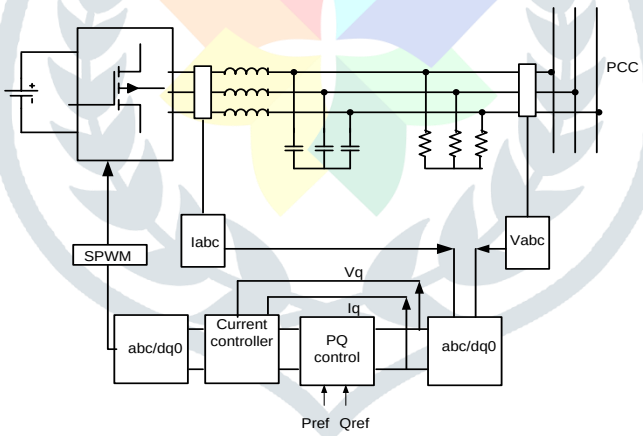

Fig 2: Layout of PQ controlling scheme

Droop control- This method is applicable for conventional synchronous generator DG where, mechanical power is controlled to maintain the frequency. In converter type of DG the variation of frequency and the voltage is controlled by linear rotational transformation as shown in fig 3. The variation of frequency develops harmonic in the network, which is controlled by introducing small inductor [13].

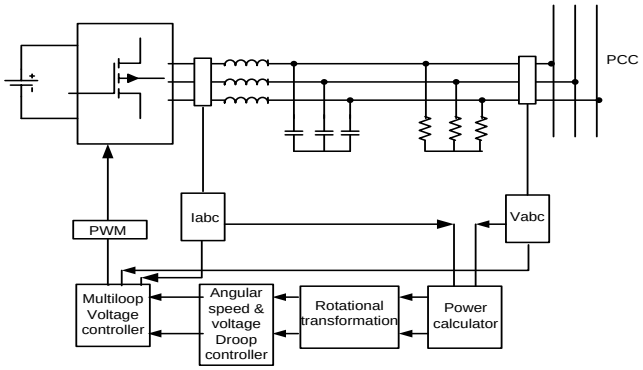

Fig 3: Layout of droop controlling scheme

V/f (Voltage/Frequency) control- The voltage difference w.r.t reference voltage and the error is controlled by low pass filter. Traditionally, frequency is controlled by active power and voltage is controlled by reactive power. In inverter based models there are two loops, first for reactive power control, which maintains voltage and second for DC voltage control which changes the active power and the frequency of the system [15].The convenient model would be combination of v/f closed loop controller with PQ controller as shown in fig 4.

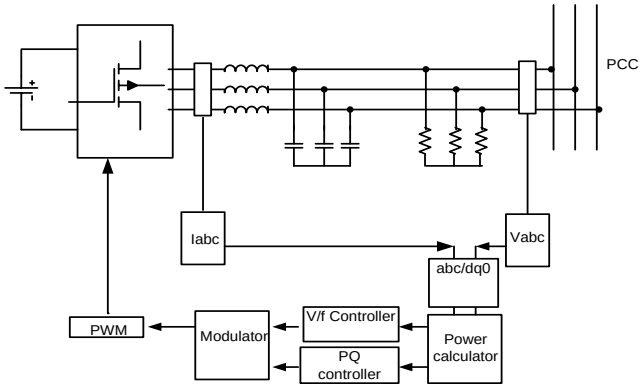

Fig 4: Layout of V/f controlling scheme

Current control- In parallel operating inverters the circulating current often affects the system. Current controller based on VSI is more sensitive toward current. It gives current harmonic under voltage distortion and hence it is preferred to work under grid connected operation. It has capability of handling over-current. This type of controller is often combined with PLL for getting reference frequency and phase [17].

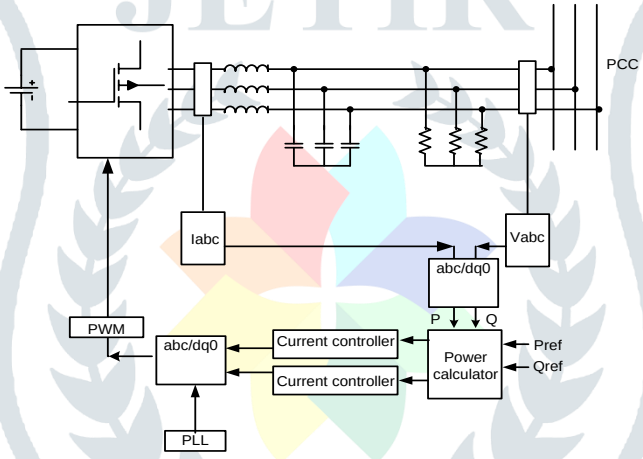

Fig 5: Layout of current controlling scheme

V. Communication interfacing

The operating commands given to the controlling units and other equipments are supervised by controller. This controller collects the entire data related to the operation. The communication link between the different units and the control room is known as communication interface. The communication interfacing is controlled by two different schemes i.e.

a) Local controlled scheme

b) Central controlled scheme

a) Local controlled scheme- In this scheme the different micro-grid units like generation unit, storage unit, load etc are controlled at remote location. The controller is present at nearby location and communication network is small.

b) Central controlled scheme- This is also called as master controller. It commands all the local controllers present at remote areas. The communication network is large and interconnected to each other as shown in fig 6.

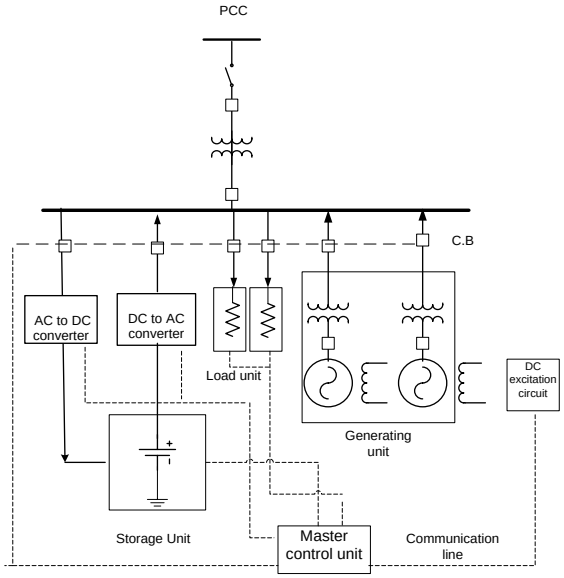

Fig 6: Typical central controlled micro-grid

The automation in distribution network is modeled using above controlling schemes. The communication line used for interfacing is generally Ethernet cable or fiber optics cable. The monitoring system is based on SCADA which represents different input, output and functional units on a single screen. The communication line and the power line are kept at suitable distant to avoid the communication interference.

VI. Conclusion

In this paper different models of micro-grid have been explained with design consideration. The various modes of operation in micro-grid, its controlling schemes and its equivalent close loop control systems are described briefly in different sections. This paper has briefly described several real micro-grid models that have been used by different countries.

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