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Microgrid Overview: Control and Future Trends

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ABSTRACT

With the improvement in power semiconductor technology a new vision of integrating non- conventional energy sources with conventional grid is becoming more practical. Microgrid, the most challenging and interested technology, is immerging as one of the best possible way of integrating non-conventional sources to the grid. The microgrid technology offers many advantages such as flexibility, expandability and environmental friendliness. One of the most interesting features of the microgrid is that it can operate in parallel with or isolated from main grid depending upon resource availability, geographical location, load demand and existing electrical transmission and distribution system.

The purpose of this paper is to describe structure, operating modes and control strategies for microgrid. The presented control strategy is based on the hierarchical control structure. These hierarchical control levels are the primary control at unit level, the secondary control at local level and the tertiary control at supervisory level. The main grid services that microgrid can offer to the main network, as well as the future trends in the development of their operation and control for the next future, are presented and discussed.

Keywords: Microgrid, distributed generation, energy storage, micro sources, islanded mode, power quality, hierarchical Control.

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I. Introduction

Microgrid is combination of distributed generation (DG), electrical energy storage devices and loads [1]. Fuel cells, PV array, wind turbine or any other alternative power sources can be used as generators in microgrid. The main role of microgrid is to provide stable operation during faults and various network disturbances. A microgrid may be in the form of shopping centers, parks, college campus, etc. The use of distributed energy resources as micro-generation can cause problems such as voltage rise, the potential to exceed thermal limits of certain lines and transformers and have high capital cost .The combination of distributed generation with energy storage and loads can be a better solution for these problems.

The proper control of DG along with electrical energy storage is necessary for more efficient and flexible operation of the grid. As microgrid consists of power electronic devices, the operation of microgrid requires both energy and power management and classification of control strategies. The most suitable control design should cover following aspects;

1. System should function within satisfactory operating limits.
2. System stability should be maintained.
3. Process of disconnection and reconnection should run smoothly.
4. Loads must be classified according to sensitivity i.e. highest to lowest.
5. If failure occurs microgrid should be able to operate in isolated mode.
6. Energy Storage System should support the microgrid and increase the system's reliability and efficiency.

This paper presents an overview of the microgrid technology and different control strategies at different levels. The paper is organized in different sections. The first section describes overview of microgrid structure and operating modes. The second section describes necessity of control of power converters in microgrid. The third section elaborates basic hierarchical control of microgrid. Fourth section deals with actual matlab simulation results of control of inverter. And Section five describes regarding application and future scope of microgrid.

I. Overview of Microgrid Structure

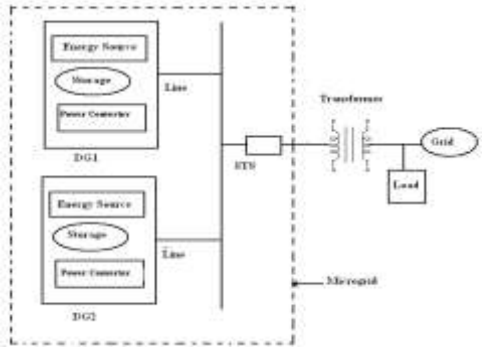

Fig1.1: microgrid structure

Figure.1.1 shows a typical design of the construction of microgrid. It consists of three distributed generation systems. The energy source in the form of DG (Distributed Generation) needs to be interfaced with the microgrid network. The inverter configuration is used to interface the source to the network. This can help in adjusting the required form (ac or dc) and required voltage level for transferring energy from the source. For smooth control during the transients due to faulty conditions in distribution network as well as in loads, interfacing of converter is used. The proposed control strategies make this technology more neat and promising over the conventional methods [2].
Following are the important key features of microgrid;

- Operating in island mode and/or grid connected.
- Providing good power quality and reliability to end users.
- Supplying energy according to system energy requirements.
- Interconnecting loads with different power generation sources and storage devices.
- Presenting itself as a single controllable entity.

Energy Sources: Different types of energy sources are used in microgrid, such as Photovoltaic (PV) system, wind turbines, small hydropower units etc.

Energy Converters:

Power semiconductor based converters have the crucial importance in the areas of distribution and management of electrical energy. In developed as well as developing countries, the use of power electronic system is rising rapidly. The main task of power electronic converters is to control and convert electrical power from one form to another. They are nothing but power electronic circuits that converts voltage and current in one form into another form. In these converters, at least one power semiconductor device is used as a static switch. The main form of conversion and converters are as follows.

AC to DC conversion (rectifier)

DC to AC conversion (inverter)

DC to DC conversion (chopper)

Energy Storage: Microgrid is combination of energy storage devices and distributed generation.Some of the applications of energy storage are improvement of power quality, load management as per requirement and supply of emergency power. Most commonly used storage devices are batteries and capacitors. They are directly connected to the bus. At normal power batteries are being charged and when normal power fails batteries discharge and provide continuous power supply to load. These devices, in a normal operating condition, take the AC power; convert it into DC to charge the batteries then again convert it back to AC for use on the load. In addition to this Storage devices are also used to store the excess amount of energy when the production is high and demand is low.. Hence energy storage system provides good stability to overall system [5].

Static Transfer Switch (STS)

The microgrid is connected to the utility system through the static transfer switch (STS) at the point of commoncoupling (PCC). When any type of interruption or fault occurs on the system this static switch disconnect microgrid from main grid in order to protect the whole system.

Operating modes of microgrid

Fig.1.2. shows basic layout for operating modes of microgrid

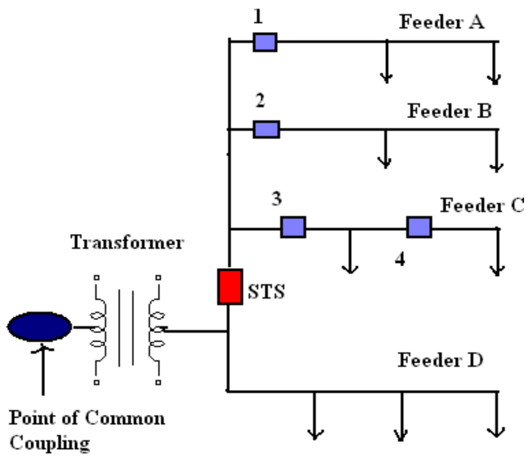

Fig 1.2.operating modes of microgrid

It consists of group of radial feeders from A to D. Radial feeders provides single path for power to flow from source to load. There is single point of connection to the utility called as point of common coupling (PCC). Feeders A-C have sensitive load which require common generation. Feeders A-C can be disconnected from main grid using static transfer switch (STS). There are four micro sources 1-4 at nodes which control the operation of the system [6].

Two operating modes of microgrid are explained as follows,

A) Grid connected mode:

For grid connected mode, power from generation can be directed to feeder D. That means feeder D is active. Static switch is closed and main grid is active. This is normal operating condition in which power is given to the utility from main grid. All other feeders A-C are inactive at this condition.

B) Islanded mode:

At abnormal condition that is when any type of fault or disruption occurs on the system it is operated in islanded mode. In case of island mode main grid is inactive. When there is problem with utility supply static switch is open to isolate sensitive loads from the power grid. As main grid is not supplying power due to any interruption, feeders A, B, C are being supplied by micro sources.

This principal feature of microgrid that, it is operated in both normal working condition and also in fault condition makes it as a very much convenient.

II. Necessity of Control of Power Converters in Microgrid

Microgrid uses converter for coupling with the grid, therefore, control of those converters has become an important concern for grid operation.For the development of modern power system, main consideration is distributed generation. For this system voltage stability and power flow limitations are the main problems related to the reliability of the system. Distributed generation has been measured as additional generation units. If the system is not controlled properly it results into in passive and inflexible networks to work in fault and emergencies. Due to lack of controllability, the system performance is low which decreases system efficiency. The distributed generation systems are close to the end consumers as compared to large scale powerplants. So it reduces overall transport loses. Proper control of DG plants combined with storage devices, improves the continuity of the supply.

The converter control can be categorized as follows:

1. An input-side converter that is an AC-DC converter
2. Grid-side converter this is a DC-AC converter.

Thus, the first control category is related to the input-side converter. Following are the main duty of the input-side controller

1. To make sure that the maximum power is extracted from the input source, generally achieved by using maximum power point tracking algorithms.
2. If grid failure occurs, the input-side controller should be able to protect the input source.

The second control category is related to the grid-side converter. The grid-side controller has many jobs.

1. It must ensure that the quality of the output power to the grid is maintained by controlling the output current
2. Some common power quality problems such as voltage dips or swells, flicker, voltage unbalance, harmonics, andtransients should be minimized.

Control the active power generated to the grid as well as the reactive power exchanged between the DG and grid

III. Hierarchical Control of Microgrid

The main objective of hierarchical control is to develop a proficient control strategy for flexible and reliable operation of power converters based on distributed generation to interconnect with the existing power system.

Proposed control strategy is based on hierarchical control levels through inverter based distribution generation. These control levels are classified into,

- Primary control at unit level
- Secondary control at local level
- Tertiary control at supervisory level

With the proposed control strategy, this control region can be expanded to the low voltage, medium voltage and high voltage distribution networks by active grid.

Basic Structure of hierarchical control

The hierarchical control is combination of the centralized control and distributed control. Its basic structure is shown in figure.

Primary Control:

The primary control is actually the distributed control. In primary control the microgrid system can operate without communication. Thus, it usually provides the effective results in microsecond including the voltage and current control for DC to DC converters. The communication line should be bidirectional.

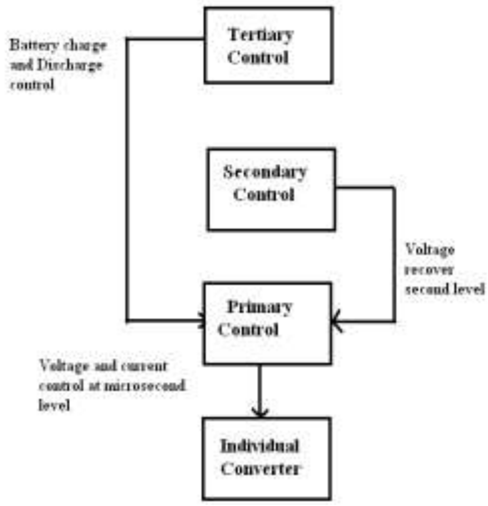

Fig 1.3.Hierachical control layout

All the local information, including the voltage and current is sent to the upper controller, which implements the tertiary control and secondary control. Here, the DC microgrid is operated in SST-enabled mode, thus SST controller is the upper controller.

Secondary Control:

Basic control functions of secondary control are,

1. Maintain and control the state variables voltages and frequency to the nominal rated values

2.Control the power exchange of interconnected grids

3.Detect and maintain local power unbalances

4. provides good voltage regulation

Therefore, secondary control provides smoothly switching before the system switches from islanding mode to SST enabled mode. The time scale for the secondary control is millisecond or second [13].

Tertiary control:

The main objectives are,

1.To restore the secondary control reserve

2.To set the microgrid voltage and frequency to their nominal values in case the secondary reserve, is not effective enough

3.To set the best possible operation of the system from an economical point of view

4.Tertiary control provides supervisory control

The objective of the tertiary control is to maintain the operating condition of battery. Thus, the tertiary control is to charge or discharge battery in DC microgrid based on battery's state of charge [13, 14].

IV. Controller for DC-AC converter i.e. Inverter

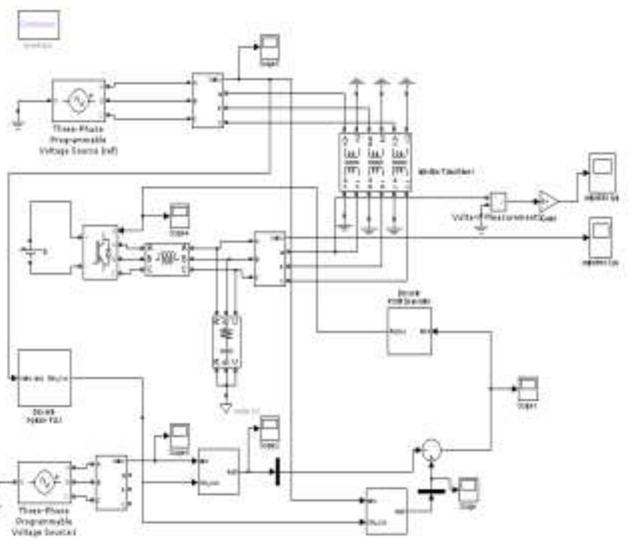

Fig 1.4.Controller for inverter

The controller diagram is shown in Fig.1.4, and both voltage and current regulators are PI regulators. For DC-AC inverter, a PI controller is designed to control the phase shift between Dc and AC links so that the output AC voltage can be maintained at the desired value.

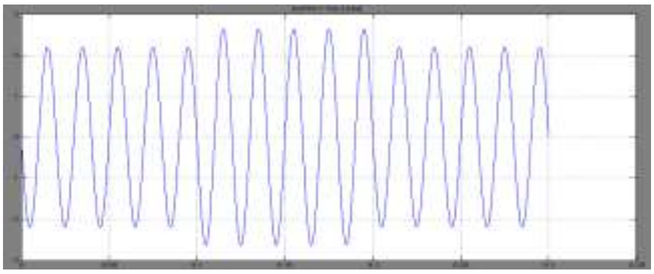

Fig 1.5. Results of voltage swell

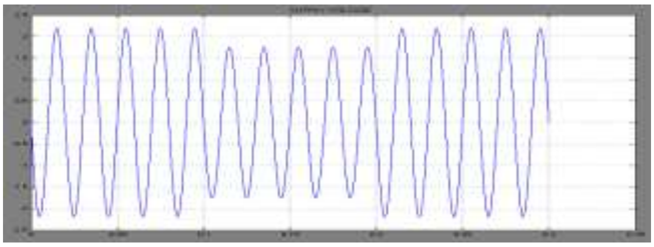

Fig 1.6.Results of voltage sag

Some common power quality problems such as voltage dips or swells, flicker, voltage unbalance, harmonics, and transients should be minimized by using above control strategy.

V. Application and Future Scope of Microgrid

Active distribution networks and microgrid with electrical energy storage will become increasingly popular because of the trend toward increasing renewable energy sources. Microgrids hold the promise of becoming a basic building block in the implementation of the next generation smart grid infrastructure. Microgrids are nothing but smaller versions of electrical grids. Like electrical grids, they consist of power generation, distribution, and controls such as voltage regulation and switch gears. However, they differ from electrical grids by providing a closer closeness between power generation and power use with better efficiency. Some of applications are,

- Microgrid provides security and independence from potential grid interruptions such as blackouts which is more beneficial, especially for critical applications running at hospitals and military bases.

- Microgrids can meet the needs of a wide range of applications in commercial, industrial, and institutional settings.

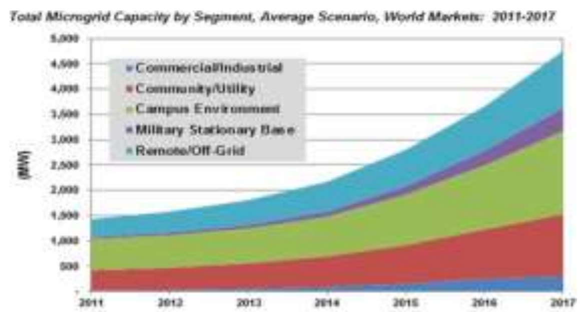

Fig 1.7.Total microgrid capacity by segment, Average Scenario, World Market: 2011-2017

- Another important application is the off-grid area of the world where one billion-plus people live without regular access to electricity. Microgrid provides continuous supply of electricity in times of crisis for critical applications like a hospital

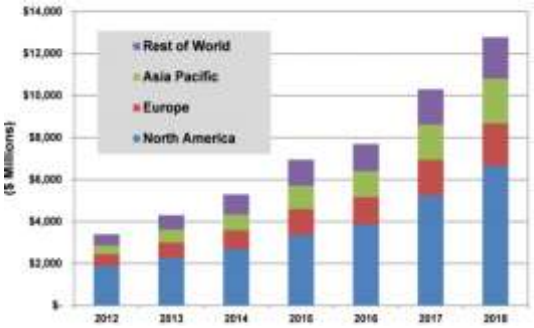

Fig 1.8.Revenue Through The Sale Of Energy During Peak Demand

- Microgrid's structure is viable platform for large entities to reduce energy costs and generate profits through the sale of energy during periods of peak demand.

VI. CONCLUSION

This paper reviews basic microgrid architecture with its operating modes in detail. In islanded mode microgrid can operate in fault and disturbances and provides continuity of the supply to consumers. This is the main advantage of microgrid system. The benefits of storage system and existing storage devices have been identified. In addition to these different hierarchical control levels are discussed. Simulation results of voltage sag and swell has been calculated for inverter. As well as the future trends in the development of their operation and control for the next future, are presented and discussed**.**

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