4) It helps in reducing the investments and increasing the revenue from this kind of system i.e. grid- connected mode.
5) Micrograms are planned in such a way that if there is surplus amount of energy that is not required to meet our load demands, it can be fed to the main grid helping in generation of the revenue.
6) Grid interconnection allows to reduce fuel operational costs by providing choice to the customer when they want to use the power from the grid specially when the cost is low.

3.2 Islanded Mode

An important characteristic of microgrid is its ability to get separated, or isolate itself from the main utility grid. The microgrid is structured in such a way that it has got the capability of operating independently, still the shift from grid connected mode to islanded mode is very challenging. It is seen in various applications that if the main grid is lost the microgrid is expected to shut down for a while and then starts acting like a backup source for meeting the local load demands.

Uninterrupted power supply is required to those loads who are more prone to the voltage disturbances and the microgrid can prove very beneficial in such cases and is very promising, will act as the backup power supply. The microgrid is isolated from the main grid because of the faults caused by transients, increase of load, it may be intentional or unintentional. In intentional islanding microgrid is disconnected from the main grid by itself may be because of the some kind of repair and maintenance work or to protect the micro sources from the instability on the main grid side. Unintentional islanding is natural and can be caused by faults, etc.

4. Control of Microgrids

To operate the microgrid in grid connected mode or isolated mode one has to design the control strategy properly so that it can allow the operation of microgrid in both the modes safely. The system may have the central controller which will control the whole system or it may have individual controller for all the micro sources. The controller controls the local frequency when isolated from the main grid by sending or receiving the instantaneous difference of real power between generation and demand, protecting the internal microgrid.

The frequency control is the challenging problem in case of isolated operation of microgrid. The rotating masses connected to the larger power systems unit are connected to ensure the stability of the system and the frequency response of the system is totally based on them. In contrast, distributed energy sources (or microgrid) are converter controlled or power electronically controlled for such operations, and hence there is no need for the rotating masses. But some microsources like microturbines and fuel cells are showing very weak response to the control signals and hence are raising the issue of load tracking in the scenario of islanded operation. The control strategy based on converter operation is utilised to ensure the response of the system to be same as obtained from connecting the rotating masses to the system. The voltage regulation must be proper as it is necessary for reliability of the power and stability without which the system can have voltage and reactive power fluctuations and oscillations. Voltage regulation is the problems faced in both the operating modes; i.e., stand-alone or grid-connected.

4.1 Centralized microgrid control:

The centralized control helps in increasing the local production, that depends on market scenario and the security constraints, by optimizing microgrid central controller of the host system to the microgrid exchanged power. This is done by setting and issuing of the control set points to distributed energy source units and controllable loads within the microgrid. Two way communication is set up between the MCC and LC of the system in order to exchange information of the centralized control strategy The communication channel is through the telephonic lines, PLC, or some kind of wireless source. The microgrid central controller takes decisions for pre-specified time intervals; e.g., every 20 minutes for the next hour or hours. The local controllers issues bids to the MCC based on the market scenario and unit capacities. Similarly, the load LCs issue bids for their demands considering their priorities for service.

Figure 2: Flow of information in centralized controlled microgrid [3]

Based on the bids issued by the microgrid central controller the LCs balances the load and demand and generates bids. To have the centralized control of a microgrid specific functions need to be implemented such as load demand, generation, heat forecasting unit commitment, economic dispatch, and security constraints.

4.2 Decentralized Microgrid Control:

This kind of control strategy believes in providing full autonomy to the local controllers of the distributed energy resources as it trusts that they are intelligent and smart enough and can communicate with each other to form a larger intelligent, smart and efficient unit. In the decentralized control scheme the main focus is not on the economy that is on generating the revenue but on the improvement of the overall performance of the system. Environmental conditions, weather conditions, etc are the main deciding factors for the decentralized scheme and hence the multi agent system is used in this control strategy.

The MAS is evolved from the classical distributed control system having the abilities to control large and complex systems. The main feature of the MAS that makes it unique from the traditional/classical system is that it has got the software which makes it more intelligent. Each unit uses its inherited intelligence to decide the market forecasting and the environmental conditions. Mult agent system uses the artificial intelligence based methods like fyzzy logic or neural network technology. An intelligent MAS must be having the most efficient and intelligent software with it and effective communication channel in it [3].

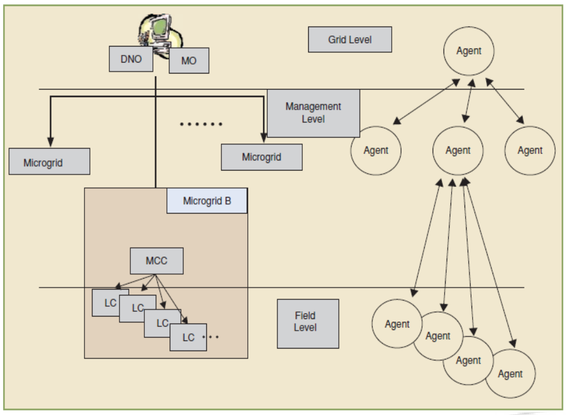

Figure 3: Schematic architecture of MAS in decentralized controlled microgrid [3]

Studies have shown that in the stand alone system the main problem is of the frequency control. As in the larger systems the frequency response is based on the rotating parts like flywheel that are connected in order to store energy [4]. But in the smaller systems the response is not appreciable because of the absence of the rotating parts like flywheel and very slow response to the control signals. Therefore converter control system is applied which was previously done by the connected rotating parts.

In both the islanded mode and the grid parallel mode the common problem faced is of voltage regulation. It is because of the reactive circulating currents injected in the sources. The control system must ensure that there is no circulating current in the system. This problem can be eliminated by using the modern day power electronic devices which adopts the method of voltage vs. reactive current droop control.

The increasing share of distributed generation (DG) units in the electrical power systems has an appreciable impact on the operation of the distribution networks which are increasingly being confronted with congestion and voltage problems. This demands for a coordinated approach for integrating DG in the network, allowing the DG units to actively contribute in the frequency and voltage regulation. Microgrids can provide such coordination by aggregating DG, (controllable) loads and storage in small-scale networks, that can operate both in grid-connected and islanded mode. Here, the islanded operating condition is considered. Analogous as in the conventional networks, a hierarchical control structure can be implemented in islanded microgrids. In recent years, many different concepts for primary, secondary and tertiary control for microgrids are studied and thoroughly investigated [5]

4.3 Primary control strategy

The primary control for microgrid consist of the power electronic based devices and the DGs. The microgrid is connected to the main grid through the static switch at the point of common coupling. Each DG consist of a source, an energy storage system, a power electronic interface (dc – ac inverter), connected to load directly or to the ac bus directly [6].

The dc ac inverter that are used are either voltage source inverter or the current source inverter. The current source inverters are used to inject current in the grid connected mode and the voltage source inverters are used to keep the frequency and voltage stability in the autonomous/isolated/islanded mode.

The inverters are programmed in such a way that they work as generators, as they include the virtual inertias through the droop method, which helps in ensuring the proper sharing of the active and the reactive power between the inverters. To restore the microgrid values to the normal values the supervisors send the proper signal using the low band width communication medium. Before integration of the microgrid to the main grid, this type of control is used to synchronize the microgrid with main utility grid, helping in the safe transition from the autonomous mode to grid-parallel mode. The main objective of the primary control is to have proper sharing of powers and this is achieved very satisfactorily [7].

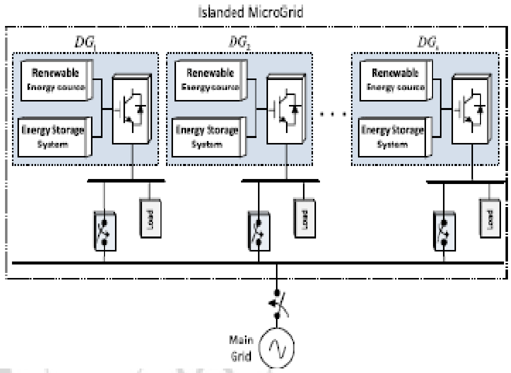

Figure 4: General structure of microgrid [6]

The primary control further consist of voltage and current loops, virtual impedance loop and droop control strategy. The droop controller and the virtual impedance loop generates the reference value for the voltage control loop. According to the real power and reactive power, the droop controller adjusts the frequency and amplitude of the voltage reference. The main purpose of adding the virtual impedance loop and the voltage reference is to maintain the output impedance of the voltage source inverter.

4.4 Secondary control

Since the primary control is local and have no communication with the other DG units, the secondary control is required which have the overall controllability of the microgrid. It utilizes a communication channel which collects the data from each of the DG unit and whatever control is required, is done. Secondary control is placed just in between the primary control source and the communication channel. The operation of the secondary control is a step by step process first it collects all the measuring data i.e voltage, frequency, active power and reactive power then average them and in last provide the primary control level with the proper control signal simulateneoulsy it removes all the steady state errors from it.

This stage of control strategy is used to compensate for the voltage and frequency deviation occurring during the operating conditions. The secondary control is so much efficient that it makes the voltage and frequency regulations to reach to zero on every change in generation or load of the system [8].

Restoration of the frequency and voltage deviations in the system produced by the droop controllers is regulated by the microgrid central controller. The main aim of the distributed networked control system is to replace the microgrid central controller with the secondary control system. This strategy not only helps in restoring the frequency and voltage deviations in the system but also balances the reactive power sharing. As there is no central controller used in the system, the problem of shutting down the whole system at the time of disturbance in the system is solved and the secondary control works independent of central controller [9].

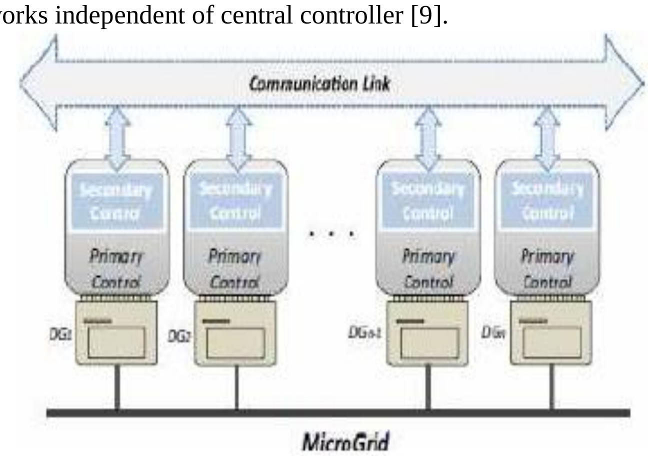

Figure 5: Networked controlled Microgrid system [6]

4.5 Tertiary Control

The main focus in this stage of the control is the economic data that is used to take decisions in the microgrid system because the power flow priority depends on it. The local or global power flow is managed by the set points of the inverter used in the system and the tertiary control scheme allows the necessary changes to be made in the set points of the system [7].

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