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Droop Control Based Power Sharing For A Microgrid With Manifold Distributed Generations.

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ABSTRACT: This paper highlights on the active power sharing of manifold distributed generators (DGs) in a microgrid. The microgrid can be functioned in two modes 1) a grid-connected mode and 2) An autonomous mode. In the course of islanded operation, one DG unit should share its output power with other DG units in exact accordance with the load. Unit output power control (UPC) is introduced to control the active power of DGs. The sustainability of the proposed power control mode is simulated under MATLAB/SIMULINK.

Keywords: *microgrid;power sharing;distributed generation; frequency;*

I. INTRODUCTION

In the existing scenario, the foremost challenge faced by the power system are ambiguity of increasing load, non-availability of fuel source, frequent load shedding, reliability and major part of power is exhausted as T&D losses. These criterions make the power system more complex. The inclusion of DG units becomes more favorable because the fuel constraint of the centralized power generation. Switching to an integration of DG renewable sources gaining the attraction rapidly, as the present centralized power generation scheme has a constraint of increasing fuel cost. These interactions result in economic operation and enhanced reliability through mutual assistance. The attractive feature of DG is that they are close to customer location. They are inexpensive than the central station power generation and its allied T&D system. Hence DG can afford enhanced service at lower cost. DG has changed the way of power system operators in order to satisfy the power supply demand by means of permitting local level power generation services.[1] The DG unit only initiates the trend of bidirectional flow of power. This results in undesirable effects of usual power flow and voltage control equipment in the present power system.A network of interconnection of power system at a local level with various DG units is called as microgrid.

The microgrid approach is targeted on designing for small scale power delivery that satisfies the demands of the constituents. At the local level, microgrid assimilates the end user and buildings with power generation and distribution. [2]-[4] Microgrid permits the end user to generate electric power in real-time at appreciably lesser cost. The ability of microgrid to employ small scale power generation and also the utilization of waste heat are the most considerable ecological reimbursement.The most recent novelty like photovoltaic (PV) cells, solar cells and fuel cells (FC) are hinge on inverter in order to link up by means of the distribution system. Therefore, VSC (voltage source converter) coupled with microgrid in parallel, to meet a common load.[5]Essentially, a microgrid performs in two operating conditions. Once the microgrid is make contact with the power grid at the intersection of PCC (point of common coupling), then the microgrid operates in grid-tied mode. Once the microgrid is standing apart from the power grid, then it operates in island mode. If there exists any break down occurs in microgrid, it will switch over to island mode automatically. This exhibits that there is no possibility of power supply interruption to the end users.The microgrid poses two power control modes viz, unit power output control (UPC) and feeder flow control (FFC). These control modes gain its importance in the view of appropriate power sharing among DG units. UPC is projected for active power sharing among manifold DGs. In this mode the DG output power is maintained constant in accordance to the power reference. While in FFC mode, the DG power output is controlled in order to maintain the feeder flow constant.[6]-[9]

This paper projects on appropriate power sharing and frequency regulation for the optimum functioning of a microgrid with DG units. The motive to give attention on the power sharing is, for the reliable performance of the microgrid to enhance the voltage and to reduce its associated losses. In autonomous operating condition, the proper power sharing is achieved only with the help of control methods.

II. MICROGRID THEORY

In this work, a microgrid system test model is taken from the CERTS model in order to achieve proper active power sharing among manifold electronically interfaced DGs in view of control modes and configurations .Unit output power (UPC) control mode is used for active power sharing.

A. Microgrid concept

Microgrid is an autonomous small scale power supply network that is designed to provide a power for a small community. It contains various microsources, controllable loads and storage devices. Two basic classes of micro sources are DC source (fuel cell, PV cells and battery storage) and AC sources (micro turbine). The DC voltage is converted to an acceptable AC voltage using Voltage source inverter. Microgrid satisfies the needs of customer such as, enhancing reliability, feeder loss reduction, voltage regulation, and increases the efficiency through the use of waste heat.

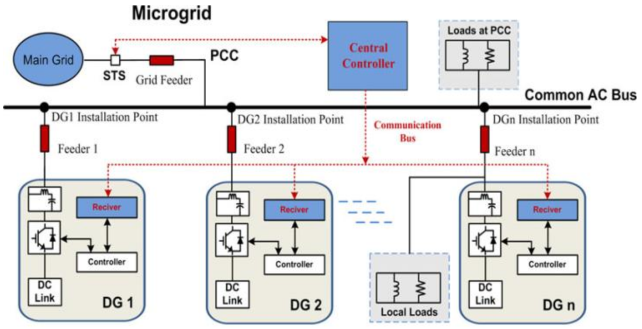

Fig.2.1. Block diagram of Microgrid

The main significant components of microgrid are static transfer switch (STS) and micro sources. The static switch has the ability to autonomously island the microgrid from disturbances such as faults, IEEE 1547 events, or power quality events. After islanding, the reconnection of the microgrid is achieved autonomously after the tripping event is no longer present. This synchronization is achieved by using the frequency difference between the islanded microgrid and the utility grid insuring a transient free operation without having to match frequency and phase angles at the connection point.[11] Each microsource can seamlessly balance the power on the islanded microgrid using a power vs. frequency droop controller. This frequency droop also insures that the microgrid frequency is different from the grid to facilitate reconnection to the utility.

B. Distributed Generation (DG)

Distributed generations are small electric power generators. Because of its size and clean energy technology, DG can be installed close to the customers. Installation & operation of electric power generation units connected to the local network or off-grid generation is characterized by:

- Generation capacity ranging from kW to MW level.
- Generation at Distribution Voltages (11kV or below).
- Grid inter-connection at distribution line side
- Inter-connected to a local grid, or
- Totally off-grid, including captive

Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy, generates electricity from many small energy sources.[5]

- Distributed generation occurs when power is generated (converted) locally and sometimes might be shared with or sold to neighbors through the electrical grid (or over the fence)
  Large central generation is not directly used
  The Public Service Commission may define only one supplier as a utility!
- Distributed generation avoids the losses that occur in transmission over long distances; energy is used nearby
- Varying wind and sunshine averages across several houses, blocks, cities, or states, stabilizing the system
  Variability of one source is reduced by dividing by the square root of the number of sources
- Supply is robust, but automatic precautions are required to protect electricity workers when main base-load power is out, and a local system might feed back into power lines
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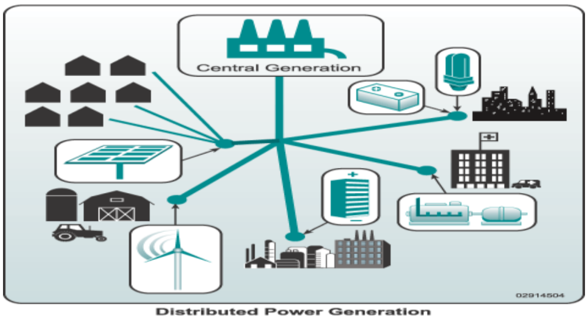


Fig.2.2. Distributed Generation

Distribution generation can be classified generally as renewable and nonrenewable DGs. Micro turbines and fuel cells are considered as dispatchable DGs due to their capability of producing active power on demand whereas the solar and wind are considered as non-dispatchable DGs due to their operation according to their maximum power-tracking concept. This type of DG's output powers are dependent mainly on the weather rather than load. Hence non-dispatchable loads are considered to be negative loads. In this paper dispatchable DG is adopted i.e. DC source.

III. POWER CONTROL MODES

CERTS proposed two active power-control modes: unit output power control (UPC) and feeder flow control (FFC). [12] During UPC, the output power of the DG is constantly controlled according to the power reference, whereas during FFC, the power flow in the feeder is manipulated according to the flow reference.

A. Unit Output Power Control (UPC) Mode

The objective of this mode is to control the power injected by a DG unit at a desired value. To accomplish this, the voltage *(V)* at the interconnection point and the DG output current (*I*) are measured as shown in Fig. 3.1 The power injection (P_{DG}) is calculated from the measured voltage and current and fed back to the generator controller (GC).

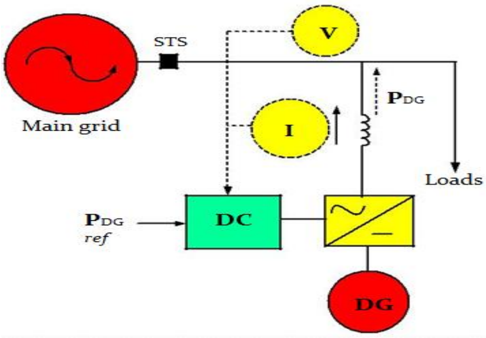


Fig.3.1. Unit Output Power Control (UPC) Mode

When the microgrid is connected to the main grid, the DG is able to maintain a constant output power regardless of the load variation, because the power mismatch can be compensated by the grid. However, during islanded operation, DGs must follow the load demand exactly. [13],[14] A power versus frequency (*P –f*) droop control has been adopted for DG power-sharing methods. This control uses the frequency of the microgrid as a common signal among the DGs to balance the active power generation of the system. *P–f* droop-based power controllers have proven to be robust and adaptive to variation in the power system operational conditions, such as frequency- and/or voltage-dependent loads and system losses. The relationship between the frequency (*f*) and the power output of a DG (*P*) can be expressed as

$$f' = f^0 - K^U(P' - P^0) \qquad \text{……….. (3.1)}$$

Where K^U is the UPC droop constant, f' and P' are the frequency and DG output power at a new operating point, and $f^0$and P^0 are the nominal values. When the load increases during islanded operation, the DG output power also increases, and the frequency decreases according to the droop characteristic. [15]

IV. SIMULATION MODEL

Fig.4.1. shows a single-line diagram of the microgrid test system model, which is connected to a main grid system by a static switch. The microgrid consists of three electronically interfaced DGs (multiple) like DG1, DG2 and DG3 and each DG has its own local loads like load1, load2, load3 respectively. Loads get supply from both utility and DG when microgrid is connected to the man grid. After few seconds, due to faults in the system static switch gets opened, results in islanded operation of microsource to supply local loads.

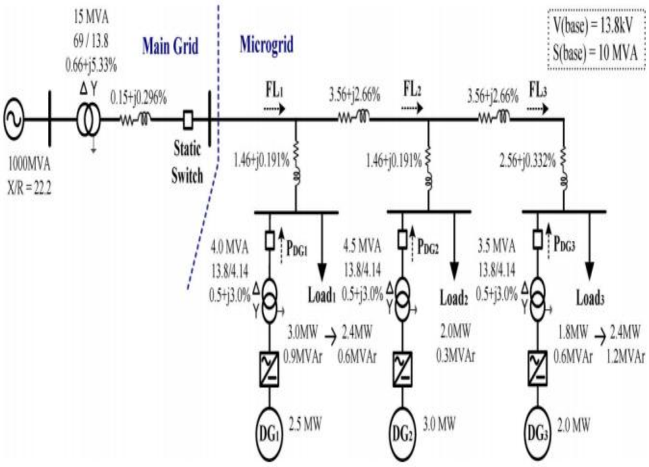


Fig.4.1. Single-line diagram for Microgrid system

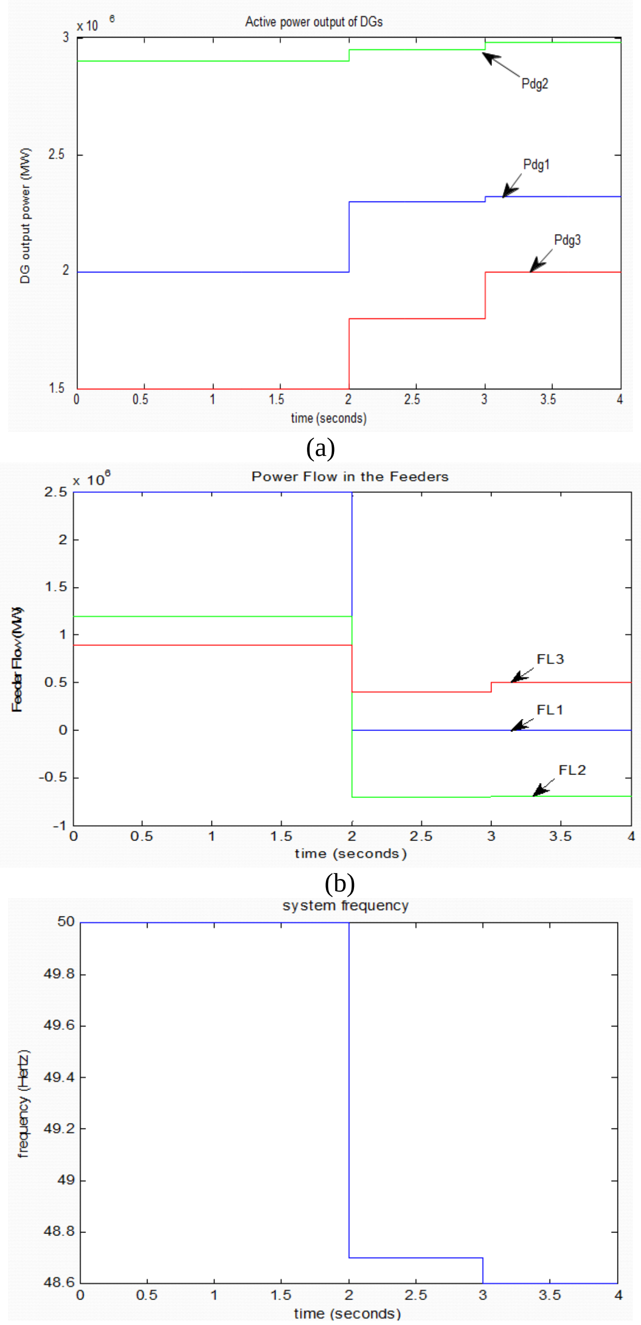
In order to meet the load demand, all the microsources should share the active power. The power sharing among multiple DGs can be achieved by considering unit output power configuration. The equation (3.1) is designed as droop control and given as gate signal to the inverter.

V. SIMULATION RESULT

The simulation is carried out in 3 cases

Case (i): Grid connected mode (0-2) sec.
Case (ii): Island mode with decrease in load 1
and load 2 (2-3) sec.
Case (iii): Island mode with increase in load 3
(3-4) sec.
At 1.2 s, the main grid compensated for the variation of Load 1, so that the power flow from the main grid (FL 1) is reduced to 2.49 MW.

After islanding at 2 s, all DGs increased their output to match the load demands. In the new steady state, the outputs of the DGs are approximately 2.28, 2.95 and 1.80 MW respectively, and the system frequency is dropped to 48.7 Hz.At 3.0 s, the outputs of the DGs are increased to the new steady-state values of 2.30, 2.99, and 2.00 MW to compensate for the variation of Load 3. Since the output of DG2 reached its maximum limit, the output changes of DG1and DG3 is greater than they would have been if no DG output limit has been violated. The system frequency is decreased to 48.6 Hz.



(a)

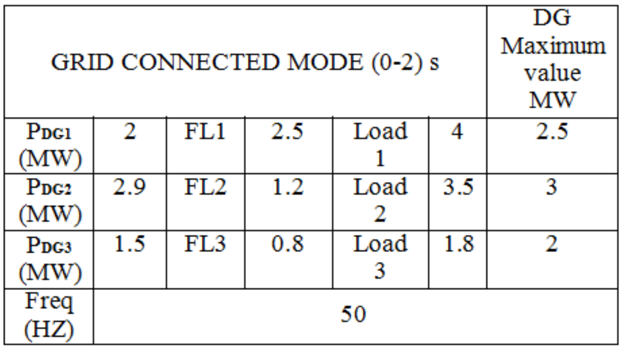
(b)

(c)

Fig 5.1. Simulation results of UPC mode (a) active power output of each DG; (b) power flow in the feeders; and (c) system frequency.

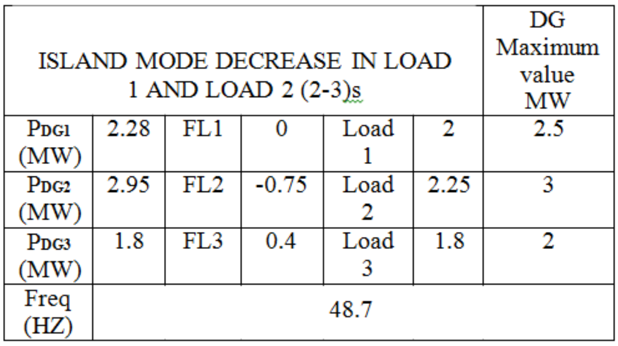
From the simulation results, a comparison table is made for three cases.
In case 1, The power generated from DG1 is 2MW and feeder flow is 2.5 MW. This satisfy the load demand of 4MW. Likewise in all the three cases, the load demand is satisfied.

Table 1: Grid connected mode – Case 1



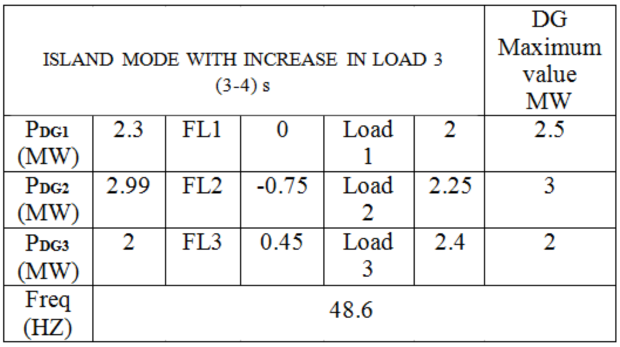
GRID CONNECTED MODE (0-2) s						DG Maximum value MW
P_{DG1} (MW)	2	FL1	2.5	Load 1	4	2.5
P_{DG2} (MW)	2.9	FL2	1.2	Load 2	3.5	3
P_{DG3} (MW)	1.5	FL3	0.8	Load 3	1.8	2
Freq (HZ)	50					

Table 2: Island mode with decrease in Load 1 and Load 2 – Case 2



ISLAND MODE DECREASE IN LOAD 1 AND LOAD 2 (2-3)s						DG Maximum value MW
P_{DG1} (MW)	2.28	FL1	0	Load 1	2	2.5
P_{DG2} (MW)	2.95	FL2	-0.75	Load 2	2.25	3
P_{DG3} (MW)	1.8	FL3	0.4	Load 3	1.8	2
Freq (HZ)	48.7					

Table 3: Island mode with increase in load 3 – Case 3



ISLAND MODE WITH INCREASE IN LOAD 3 (3-4) s						DG Maximum value MW
P_{DG1} (MW)	2.3	FL1	0	Load 1	2	2.5
P_{DG2} (MW)	2.99	FL2	-0.75	Load 2	2.25	3
P_{DG3} (MW)	2	FL3	0.45	Load 3	2.4	2
Freq (HZ)	48.6					

VI.CONCLUSION

A power-sharing method is developed for dispatchable DGs, while non dispatchable DGs are considered to be negative loads. During UPC, the DG output power is regularly maintained according to the power reference. This paper has projected the active power-sharing principles of manifold DGs in view of its control modes. In the course of island mode of operation, the load demand has been matched by DGs alone. In the application of UPC mode, the islanded mode operation is more advantageous than the grid connected mode. The simulation results have indicated that all DGs share the proper amount of power especially in islanded mode.

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