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Study of Droop Control Method of Islanded Mode Microgrid

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Abstract— in this article, the design of micro grid in islanded mode and droop control of micro grid have been studied. Combination of loads with local generator units is termed as micro grid. It can work either in Grid connected mode or in Islanded mode. Control of micro grid is an important aspect in study of micro grids. There are several methods to control a micro grid. (Among them Droop control deals with change of active and reactive power with change in frequency and supply voltage respectively). Our aim is to design an islanded mode micro grid and to study its variations in active and reactive power with frequency and voltage in MATLAB SIMULINK environment.
Thus the following article covers the importance of emerging micro grid technology, the concept of a micro grid and its main components and design of a model of a micro grid in Islanding mode using Mat lab /Simulink software, this is achieved by designing two Voltage Source Inverters (VSI) with a LCL filter to obtain a ripple free, sinusoidal output voltage and current waveform.
This article also focuses on paralleling of two inverters supplying a single phase load and sharing of active and reactive power, and then the basic control strategy for parallel operation, and analysis of power distribution and stability are discussed.

Keywords—Droop Control, Islanded Mode Micro grid, Simulation Design of Micro grid

I. INTRODUCTION

Nowadays power and energy are two basic necessities in this modern world. As the demand for energy is increasing day by day, so the ultimate solution to this ever increasing problem is to introduce renewable energy sources. But this renewable energy sources are not continuously available in nature at the same level as different renewable energy sources have different energy levels at different time duration, it is difficult to bring them all to the single DC bus. Besides, this single unit is insufficient and unreliable to supply the energy to the large demand .This gives rise the idea of Distributed Energy Sources [1] .

Thus, distributed power supply is defined as the replacement of a single UPS unit with multiple smaller UPS units in parallel which increases the reliability as well power capability of the supply system. A wide range of prime mover technologies can be used for distributed energy resources; Such as gas turbines and internal combustion engines which are traditional technologies and some useful sources like fuel cells, wind power, photovoltaic systems must have inverters to convert the prime mover's output power before generating power to the grid. Thus control of inverters is the basic principle of distributed energy sources.
But the technical difficulties of this distributed technology are the control of a significant number of distributed energy resources. Thus in order to improve its application and stability the better way is to rebuild all distributed energy resources and associated loads as a subsystem or a "micro grid"[2].
According to the CERTS micro grid, it has three basic components A number of distributed micro sources.
For the high stability of power supply and so on, sensitive loads with special requirements. A static switch between the micro grid and main grid which can be implemented to disconnect the sensitive loads from the grid when required [3].

Components of a typical micro grid are shown in Fig 1.

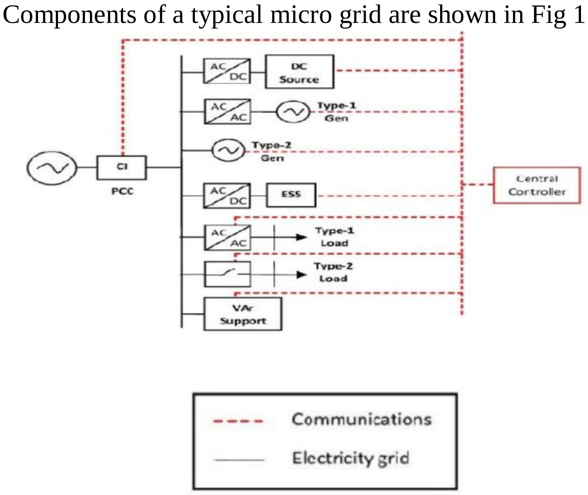


Figure1. Micro grid general component

Section I which introduces the paper, following sections are as follows: Section II describes Droop Control Method elaborating f-P droop Characteristic and V-Q droop characteristic, Section III describes Parallel operation of Voltage Source Inverters and Simulation Design of the model with the component table, Section IV contains the simulation results along with the table showing that the loads are performing parallel operation under various loading condition and section V concludes the article describing future scope of this work.

II. DROOP CONTROL

The main principle of droop control is to use the exchange of active and reactive power between a generator or storage unit and the grid to control the magnitude of grid voltage and frequency. Grid impedance in transmission line is mainly inductive and thus grid voltage magnitude is influenced most by reactive power. The active power influences grid voltage phase angle or frequency [3].

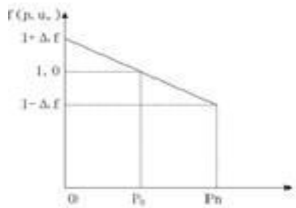
Control strategy of micro sources is the key to achieve stable operation of micro grid. This control is realized through the control of power electronic inverters. As the micro sources are equivalent to a Voltage Source Inverter (VSI), control strategies are realized by controlling the current. This control must ensure the voltage and frequency of the micro grid within the standard range and must maintain the power quality in both grid-connected and isolated operating modes. Inverters of a micro grid system can be controlled either by Constant Power Control (P/Q control) or by Voltage and Frequency Control (V/f Control). Both are based on droop characteristics.

I. Constant power control :

Basic function of inverters in micro grid system are to maintain an interface between a micro source and a micro grid. Constant power control process is executed by controlling the active and reactive power output of micro sources which is equivalent to the current controlled voltage sources. By setting the reference value of active and reactive power, micro sources can inject required power into the system. This method is generally used in grid operating mode, reference voltage and frequency are provided by the power grid. The frequency versus active power droop (f-P) characteristic curve is shown in Fig. 2(a), and voltage versus reactive power (u-Q) characteristic curve is shown in Fig. 2(b), where f_0 and V_0 are the base frequency and voltage respectively, and P_0 and Q_0 are the temporary set points for the active and reactive power of the machine respectively [4].

II. Voltage and Frequency (V/f) Control

In this method voltage and frequency are determined from the rate of droop characteristics and the power exchange between micro source and load. The basic function of this control method is to sustain the voltage and frequency of the isolated micro grid, to ensure stability of the output voltage and frequency. By adjusting output power of the micro sources, the frequency and voltage of the micro grid could be returned to the rated values, that is , the droop characteristic curves can be shifted left and right to maintain the frequency and voltage of the system, which is shown below in Fig. 2.



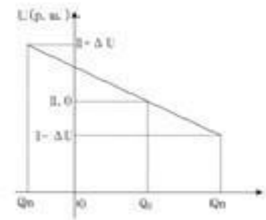


Fig.2(a). f-P droop characteristics Fig.2(b). V-Q droop characteristics

Fig. 2.Droop characteristics shared by micro sources

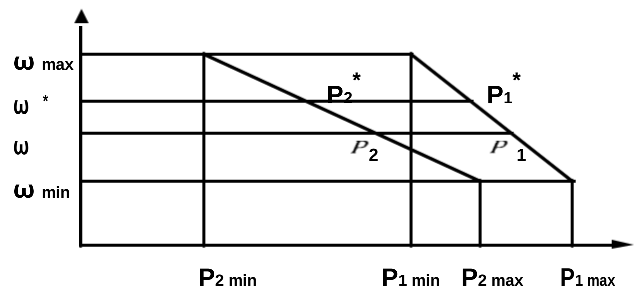


Fig. 3. Active power and frequency droop characteristics

The conventional droop methods can be expressed as:

$$\omega = \omega^* - m(P - P^*) \quad (1)$$

$$E = E^* - n(Q - Q^*) \quad (2)$$

E = Amplitude of inverter output voltage
E^* = Amplitude of inverter output voltage at no load
ω = Frequency of the inverter
ω^* and E^*= Frequency of the inverter at no load
m and n = Proportional droop coefficients
P = Active power of inverter Q = Reactive power of inverter
P^* = Active power of inverter at no load
Q^* = Reactive power of inverter at no load

III. PARALLEL OPERATION AND SIMULATION DESIGN

Control of frequency is the main process for Droop Control method. It controls the flow of active power. Parallel operation is done among the Voltage Source Inverters for controlling them under droop control method.

In Islanding mode operation droop method is very useful to generate proper power sharing between the UPSs. However power sharing of each battery must be taken into account in this case. Thus m and consequently n, droop coefficient can be adjusted, which is inversely proportional to the charge of the batteries.

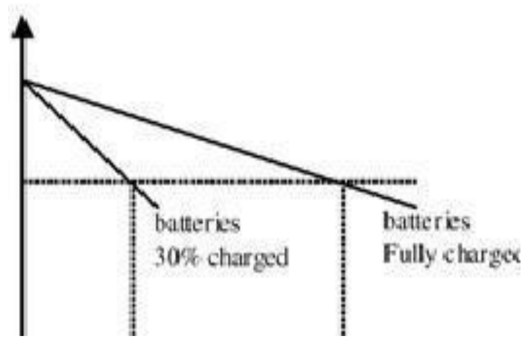


Fig 4. Droop characteristic in function of the battery charge level

Here droop co-efficient m = m_{min}/α, where m_{min}= droop coefficient at full charge and α = level of charge of the batteries (1= fully charged and 0 = empty). In MATLAB Simulation environment parallel operation of Islanded Mode Micro grid can be studied using the following model shown in fig (5). Components used in the shown model are mentioned in Table I.

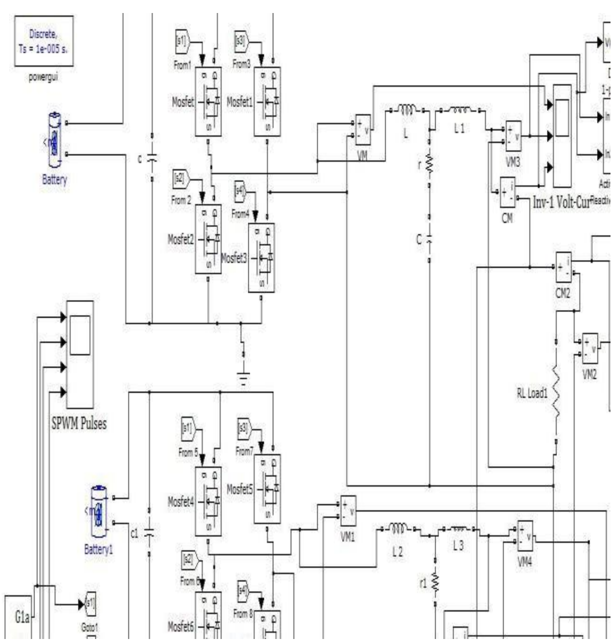


Fig.5. Design of islanded mode micro grid performing parallel operation

Table 1.Design Parameters Of Matlab Simulation

SYMBOL	PARAMETER	VALUE
E	Grid Voltage Amplitude	220V(r.m.s)
f	Grid frequency	50Hz
V_{DC}	DC Voltage	360V
L_1	Filter inductance	For Inverter 1:10.7 mH For Inverter 2: 9.5 Mh
L_g	Grid inductance	For Inverter 1.3 mH For Inverter 2.4 mH
C_f	Filter Capacitance	For Inverter 12.7µF For Inverter 10.4 µF
R	Damping resistance	11.2Ω
P	Active power	2 kw
Q	Reactive power	1.5 KVA
Q	Reactive power	1.5 KVA

DESIGN OF LCL FILTER:

First, the base values need to be calculated. These values are later used for calculating the filter components.

$$Zb = U_n^2 / S_n \qquad (3)$$

$$Cb = 1/(w_n * Z_b) \qquad (4)$$

At first the value of inductance (Li) will be calculated, it reduces the ripple in output current up to 10% of the nominal amplitude Equation (xi) is used to calculate the value of inductance.

$$Li = U_{dc} / 16 f_{s\Delta} I_{lmax} \qquad (5)$$

In case of a design of filter maximal capacity of variation of power factor by the grid is 5%. Multiplication of system base capacitance Cb will determine the value of filter capacity.

$$Cf = 0.05Cb \qquad (6)$$

The grid side inductance Lg can be calculated from the equation (7)

$$Lg = rLi \qquad (7)$$

The last step in the design is the control of the resonant frequency of the filter.

There must be a difference between resonant frequency and grid frequency and enough attenuation must be present in the switching frequency of the converter. The value of resonant frequency can be determined using equation (8).

$$f_{res} = ½*\pi[(L_1 + L_2)/L_1 *L_2*f_{sw}]^{0.5} \quad (8)$$

f_{sw} = Switching Frequency of filter

The capacitor is connected in series with the resistor. This reduces oscillations and increases stability of the filter. This is known as “passive damping”.

Though it is simple and reliable, yet the heat loss in the system increases, thus efficiency of the filter decreases. Damping resistor can be determined using equation (9) [5].

$$R_{sd} = 1/ (3*\omega_{res} Cf) \quad (9)$$

So-called “active damping” methods with a virtual resistor were therefore developed.

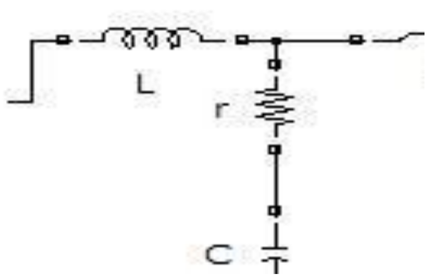


Figure 6. Design of LCL filter

IV. RESULTS AND DISCUSSION

Simulation Results:

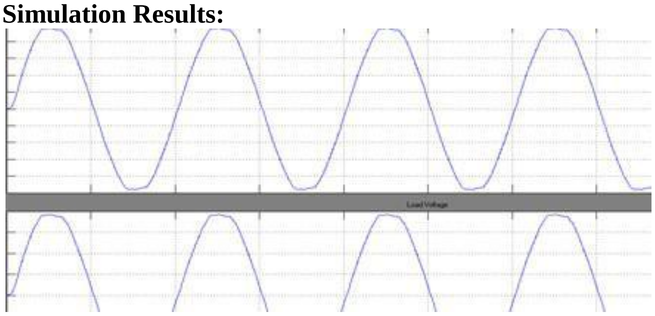


Figure 7.Waveform of load current and voltage after connecting LCL filter

Because of design of two different LCL filters there is a fall of frequency with increase in load (more than 1.5 KW). The table 2 is as given below:

Table 2. Droop Control Performance of the System

Total Load	Load (P1) (W)	Load (P2) (W)	Frequency (f1) (Hz)	Frequency (f2) (Hz)
1800	971.9	854.2	50.04	50.01
1900	1022	900.1	50.06	50.03
2000	1072	945.7	50.07	50.06
2200	1170	1036	50.04	50.08
2400	1267	1125	49.95	50.03
2600	1363	1212	49.9	49.94
2800	1457	1298	49.87	49.89
3000	1549	1383	49.85	49.85
3200	1639	1466	49.89	49.83
3400	1728	1547	49.95	49.87

V. CONCLUSION & FUTURE SCOPE

This work deals with parallel operation of voltage source inverters employed in UPS.The results are obtained for R-load in MATLAB Simulink. Parallel operation of the inverter provides a way for load current to get properly shared. It also avoids the circulating current between the inverters.

The main aim of this article is to investigate the behaviour of a micro grid during island operation mode. However, it is not involved in detailing in dynamic modelling. Rather, it just gives a brief overview of the behaviour of a micro grid and proposes a method that can be employed in order to control the system.

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