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A Power Quality Improvement for Microgrid Inverter Operated In Grid Connected and Grid Disconnected Modes

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Abstract

The renewable energy based distributed generators (DGs) will plays a dominant role in electricity production. A micro grid consists of clusters of load and distributed generators that operate as a single controllable system. The interconnection of the DG to the utility/grid through power electronic converters has raised concern about safe operation and protection of the equipments. The main objective of this paper is too focused on the power quality improvement in micro grid. In the distributed power system, the increased infiltration of nonlinear loads and power electronic interfaced distribution generation systems creates power quality issues such as voltage unbalance, frequency regulation and harmonic elimination.

Keywords*: Micro grid Inverter, Grid-connected mode, Grid-disconnected mode, Hysteresis Current*

1. Introduction

A micro grid is a cluster of interconnected distributed generators, loads and intermediate energy storage units that co-operate with each to be collectively treated by the grid as a controllable load or generator [1]. It is connected to the grid at only one point, the point of common coupling or PCC. In general, semiconductor switch is used in main power system in order to operate in both the grid-connected mode and the islanded mode. Micro grid operated in both the grid-connected and the islanded modes should be protected against all types of faults. Micro grid inverter which focuses on both operation modes of Grid-connected and Grid-disconnected is implemented for micro grid control. If the system will cut off from the service at some stage in huge actions (i.e. faults, voltage collapses, frequency deviations), or it may also deliberately disconnect when the quality of power from the grid falls below definite standards.

2. Microgrid

Microgrid Architecture

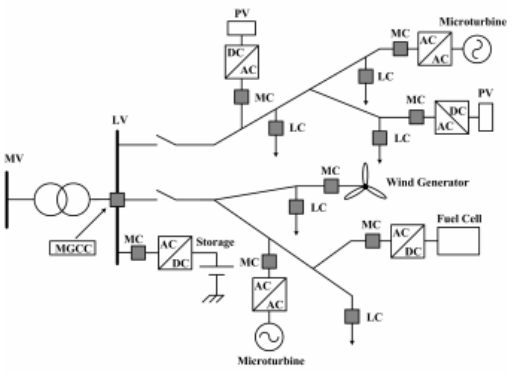

Figure 1. MG Architecture, Comprising MS Loads and Control Devices

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The microgrid basic structure is shown in Figure 1. Microgrid is included in several small powers and storage systems, which banded together to the load power through the circuit breaker and the static switch connected to the grid.

Microgrid Operation Mode

The microgrid can operate in grid-connected mode or in island mode. In grid-connected mode, the microgrid either draws or supplies power to the main grid, depending on the generation and load mix and implemented market policies. The microgrid can separate from the main grid whenever a power quality event in the main grid occurs [2].

3. Static Switch

The static switch has the task of disconnecting all the sensitive loads from the grid once the quality of power delivered starts deteriorating. The static switch does not disconnect the local system from the grid, but it disconnects only the sensitive loads.

There are two main reasons to adopt a static switch to implement the connection and disconnection from the grid: first a static switch does not have mechanical moving parts, therefore its operating life will be extensively elongated compared to a traditional contactor with moving parts. The second reason to use a dedicated switch is because during reconnection with the grid a complex series of synchronization checks need to be performed.

Inverter Topology

As shown in Figure 2, the bi-directional inverter is composed of dc–dc and dc–ac circuits. The bi-directional inverter can operate in either grid-connected mode or islanded mode. When the bi-directional inverter operates in grid-connected mode, the external grid provides the reference voltage and frequency to it, and the bi-directional inverter, adopting PQ control, controls the power flow in the dc–dc and dc–ac circuits by adjusting the dc bus voltage. When the bi-directional inverter operates in islanded mode, battery units provide the reference voltage and frequency to the system, and the bi-directional inverter, adopting V/F control, controls the output voltage and frequency by adjusting the dc bus voltage.

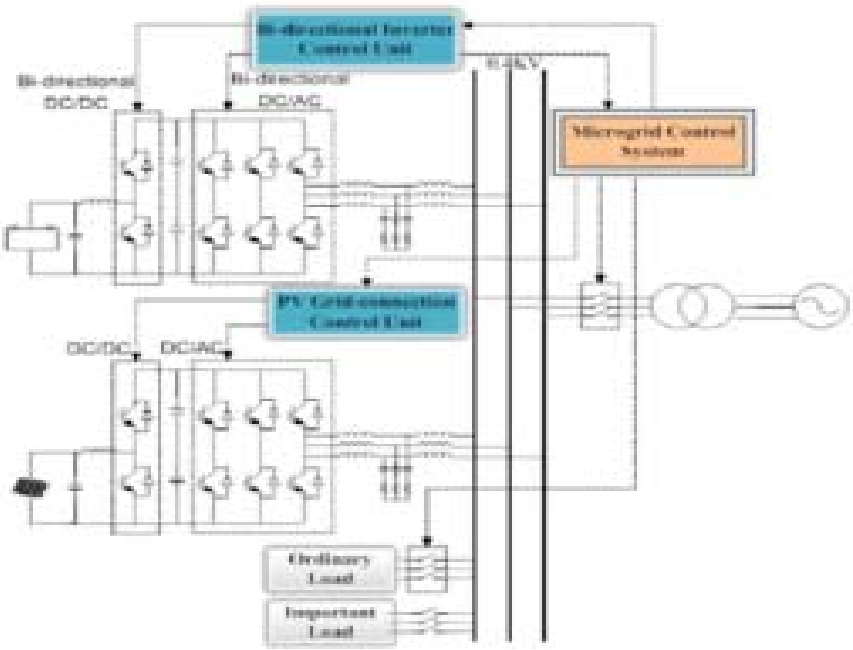

Figure 2. Inverter Topology

In the control model for inverter circuits, the basic thought for the high-frequency SPWM modulation mode is to compare the sinusoidal modulation signals with the carrier signals (such as triangular wave) to get the received pulse which controls the power switching devices. We can establish frequency domain transfer function G(s), Ls for inductance, 1 / Cs for capacitor, the relationship between output voltage Uo(s) and A, B between two voltage

$$G_0(s) = \frac{U_o(s)}{U_i(s)} = \frac{\frac{1}{R}+Cs}{\frac{1}{\frac{1}{R}+Cs}+Ls} = \frac{1}{LCs^2+\frac{L}{R}s+1}$$

$$G(s) = \frac{U_o(s)}{U_{rm}(s)} = \frac{U_0(s)U_i(s)}{U_i(s)U_{rm}(s)} = k.\frac{1}{LCs^2+\frac{L}{R}s+1}$$

4. Island Operation of Microgrid

When a micro grid is grid-connected, it behaves as a controllable load or source. It should not actively regulate the voltage at the PCC [3]. Furthermore, the harmonics and dc current it injects to the grid should be below the required levels. During this mode of operation, the primary function of the micro grid is to satisfy all of its load requirements. The micro grid should disconnect when an abnormal condition occurs in the grid. According to the transfer function of the expression can be the equivalent block diagram shown in Figure 3.

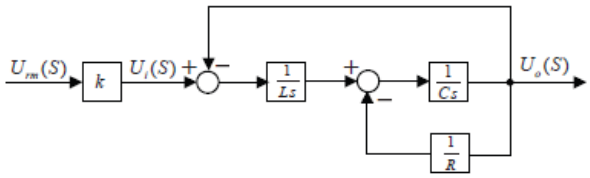

Figure 3. Closed Loop Control Voltage Equivalent Circuit

5. Grid Connected Mode

When a I is grid-connected, it behaves as a controllable load or source. It should not actively regulate the voltage at the PCC. Furthermore, the harmonics and dc current it injects to the grid should be below the required levels. During this mode of operation, the primary function of the I is to satisfy all of its load requirements and contractual obligations with the grid. When the inverter connects the grid, the grid can be regarded as an infinite capacity of ac voltage source. If the inverter adopts voltage control mode, it is easier to produce a large circulation, which is a strong impact for the inverter and the grid. The use of current control mode, only the need to control the inverter output current tracking the voltage of the grid, while setting the size of the output current, you can achieve the stability of the parallel operation, the control method is relatively simple and the results are better, so it has been widely used [4, 5, 6, 7].

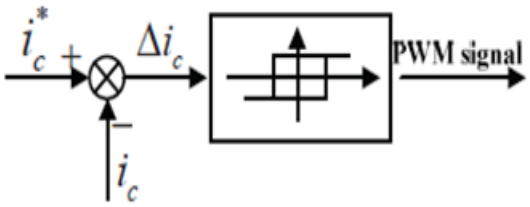

Figure 4. Hysteresis Current Control Visual Aid

Comparison of hysteretic current mode of the instantaneous way shown in Figure 4, i_c

as the comparator hysteresis loop width, when the command current i_c^* and net current i_c rise the width than the difference, the hysteresis comparator generates PWM signal for controlling power devices to adjust the grid-connected current shown in Figure 5.

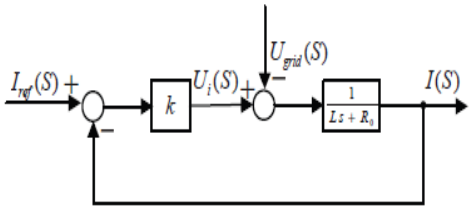

Figure 5. Closed Loop Current Circuit

6. Switching between Grid-Connected Operation and Grid Disconnected Operation

As the voltage drop, fault, power outage maintenance and other causes interruption of external power connection, Micro grid inverter can smoothly transform from Grid connected operation to Grid-Disconnected operation. Micro grid Inverter provides power to important loads. After faults remove, the static switch closes; micro grid inverter can steadily switch from Grid-disconnected operation to Grid-connected operation. During the switching process, the voltage of load is very stable.

The amplitude, phase and frequency do not change. And the grid has no effect to the operation of micro grid inverter in the connected-grid mode. Connected-grid, the grid begins to provide energy to the load, while it provides reactive power to micro grid in a few cycles.

7. Simulation Results

The simulation results can be seen from the above, using hysteresis current loop control strategy, microgrid inverter output current is stabile and low distortion. When the load changes, the current flows through the load also changes, and the voltage for the load always maintain a constant voltage.

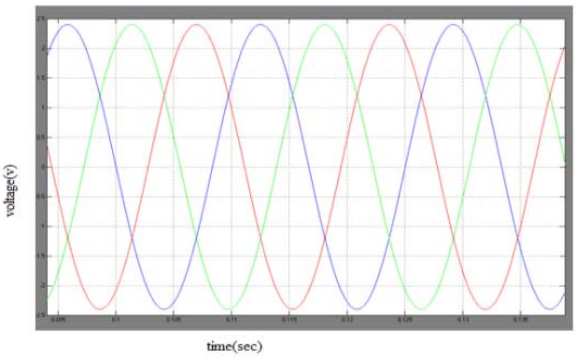

Figure 6. Sine Modulation Waveform

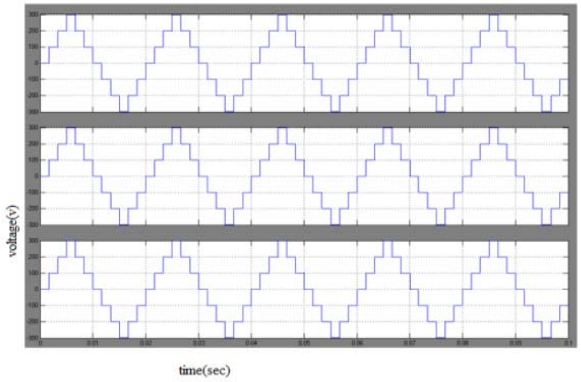

Figure 7. 3ϕ Seven Level Multilevel Inverter Waveform

In the control model for inverter circuits, the basic thought for the high-frequency SPWM modulation mode is to compare the sinusoidal modulation signals with the carrier signals (such as triangular wave) to get the received pulse which controls the power switching devices.

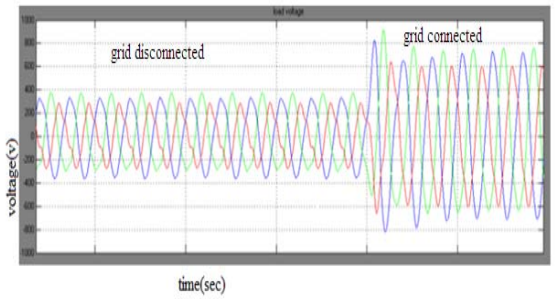

Figure 8. Load Voltage Waveform

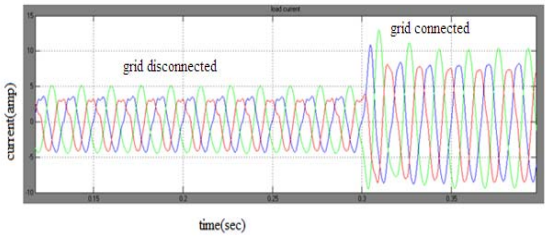

Figure 9. Load Current Waveform

As the voltage drop, fault, power outage maintenance and other causes interruption of external power connection, microgrid inverter can smoothly transform from Grid-connected operation to Grid-disconnected operation. Microgrid inverter provides power to important loads. After faults remove, the static switch closes; microgrid inverter can steadily switch from Grid-disconnected operation to Grid-connected operation.

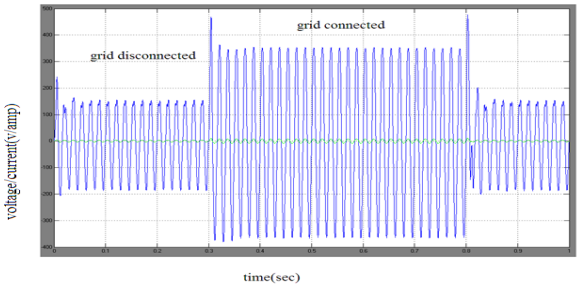

Figure 10. Load Voltage/Current Waveform For One Phase

When the inverter connects the grid, the grid can be regarded as an infinite capacity of ac voltage source. If the inverter adopts voltage control mode, it is easier to produce a large circulation, which is a strong impact for the inverter and the grid.

8. Conclusion

Power quality improvement for microgrid inverter operated in grid connected and grid disconnected modes summarizes the traditional independent inverter and Grid-connected inverter control strategy, combining the distributed power and microgrid inverter characteristics, a suitable for microgrid inverter control strategy is put forward. On the Grid-disconnected operation microgrid inverter supplies the important loads that ensures load voltage and frequency stability.

Grid-connected operation and Grid-disconnected operation, and switching operation of the system has good performance. The system controller design is simple, practical and efficient, easy to implement. The simulation results confirmed the effective performance of the proposed configuration in enhancing the power quality and reliability of the microgrid in which it was implemented.

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