A Parallel Processing Uninterruptible Power Supply for Sudden Voltage Fluctuation for Computer Applications

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ABSTRACT

This paper deals with a parallel processing uninterruptible power supply (UPS) for sudden voltage fluctuation in computer applications to integrate power quality improvement, load voltage stabilization and UPS. To reduce the complexity, cost and number of power conversions, which results in higher efficiency, only one voltage-controlled voltage source inverter (VCVSI) is used. The system provides sinusoidal voltage at the fundamental value of 220V/60Hz for the load during abnormal utility power conditions or grid failure. Also, the system can be operated to mitigate the harmonic current and voltage demand from nonlinear loads and provide voltage stabilization for loads when sudden voltage fluctuation occur, such as sag and swell. System operation simulation demonstrates that the system protects against outages caused by abnormal utility power conditions and sudden voltage fluctuations and changes.

1. Introduction

Computers and automatic equipment are widely used in homes, offices, manufacturing, industrial and commercial applications. With the growth of information systems, internet data centers, on-line banking systems, life support system, and other similar applications, uninterruptible power supply (UPS) are being researched and developed to improve the available power quality for nonlinear loads and to protect critical equipment cause from abnormal utility power conditions, voltage transients, and voltage sag and swell[1]. According to the National Power Laboratory (NPL) power quality study [2], voltage sags and under-voltage account for the largest percentage of these disturbances at 59.6% of the total. Voltage swells, or surges, and over-voltages represent 28.9% of these disturbances, impulses account for 8.1%, and outages account for the other 3.4%. This shows that load voltage stabilization is the most important issue for computer applications. Hence, it is generally expected that the UPS will perform the following functions [3-5].

1) Load voltage stabilization (±5% voltage regulation) in both normal and abnormal utility power conditions;
2) Supply of clean and uninterrupted power to the loads;
3) Harmonic mitigation ($THD<5\%$) in both normal and abnormal utility power condition.

In this paper, a parallel processing UPS using a bi-directional VCVSI for sudden voltage fluctuation in computer applications is presented. The main purposes of this system are to compensate the current harmonic and reactive power demand from nonlinear loads, to support the load voltage stabilization during sag and swell voltage fluctuations, and to supply clean and uninterrupted power during abnormal utility power conditions at the point of installation for power distribution to critical loads. The operation of the proposed system is confirmed through simulation and its usefulness is discussed.

2. System description and analysis

A typical configuration of the parallel processing UPS using a single-phase bi-directional VCVSI is shown in Figure 1. The system consists of a bi-directional VCVSI, a decoupling inductor, Xm, and a battery bank.

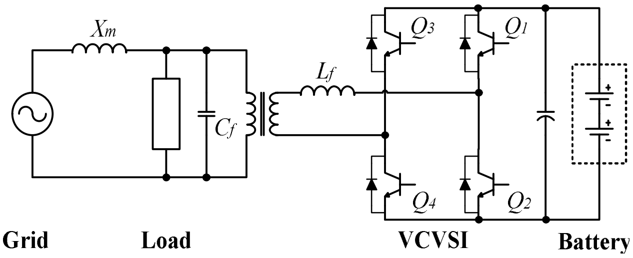

Fig. 1. Schematic diagram of a parallel processing UPS

The VCVSI is synchronized and connected to the grid through the decoupling inductor to prevent large power flows to or from the grid. The VCVSI is connected to the battery, providing bi-directional power for rectification, charging and inversion (UPS) flow capability between the battery and the AC side. The maintenance of the load voltage and power flow of the system is controlled by adjusting the amplitude and phase angle of the VCVSI output voltage, with respect to the grid voltage. In normal mode, the gird supplies power to load without any power conversion. The VCVSI supplies or compensate the required reactive power demand of the load. In the UPS mode, the system provides sinusoidal voltage at the fundamental value, 220V/60Hz, for the load during abnormal utility power conditions or grid failure.

Figure 2 shows a simplified, equivalent schematic diagram of a parallel processing UPS using a VCVSI. The decoupling inductor is an essential part of any VCVSI, as it makes power flow control possible.

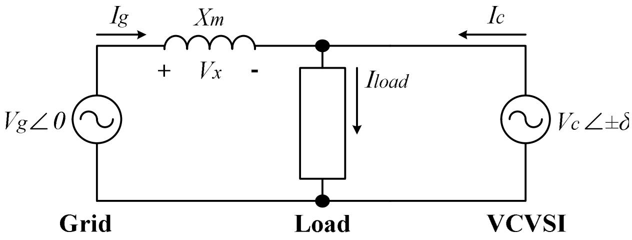

Fig. 2. The equivalent circuit diagram of a parallel processing UPS

Assuming the load voltage, $V_{load}=V_c$, is kept at a constant 220V, then the decoupling inductor voltage, V_x, of Fig. 2 can be expressed as (1)

$$V_x = V_g\angle 0 - V_c\angle\delta \tag{1}$$

In steady state condition, the current flow from the grid through the decoupling inductor can be expressed as (2)

$$I_g = \frac{V_x}{jX_m} = -\frac{V_c\sin\delta}{X_m} - j\frac{V_g - V_c\cos\delta}{X_m} \tag{2}$$

The phase angle(δ) could be both lagging or leading, providing either active power flow from the grid to the VCVSI, or vice versa. In the lagging phase case, active power flows from the grid toward the load. The higher phase angle results in more active power supply to the load or inverter from the grid. It means that the proposed system can be providing bi-directional power flow, both charging and discharging, between the battery and the grid by controlling the phase angle. Therefore, in charging mode, the active power flow from the grid is expressed as (3)

$$P_g = P_{load} + P_{bat} \tag{3}$$

In charging mode, power angle can be calculated as (4)

$$\delta = \sin^{-1}\left[-\frac{(P_{load}+P_{bat})X_m}{V_g V_c}\right] \tag{4}$$

From equation (4), when the required charging power is increased, the phase angle is increased. When the battery is fully charged, the phase angle is decreased.

3. Simulation results

A PSim simulator was used to verify the operation of the proposed system. Table 1 illustrates the simulation condition and parameter values.

Table 1 System parameters and specifications

Parameter	Value	Parameter	Value
Vac	220[Vrms]	Vdc(Battery)	200[V]
Frequency	60[Hz]	Fsw	10[kHz]
Full load	1[kVA]	Lm	42[mH]
δ_{max}	20°	Transformer	1:2

Figure 3 indicates that the VCVSI can mitigate the harmonic current of a nonlinear load demand and the grid supplies the remaining active power. In normal mode, the VCVSI prevents any lower order harmonics from being injected into the grid. The harmonic spectrum of the load voltage, grid current, load current and VCVSI current with the nonlinear load, as shown in Fig. 4.

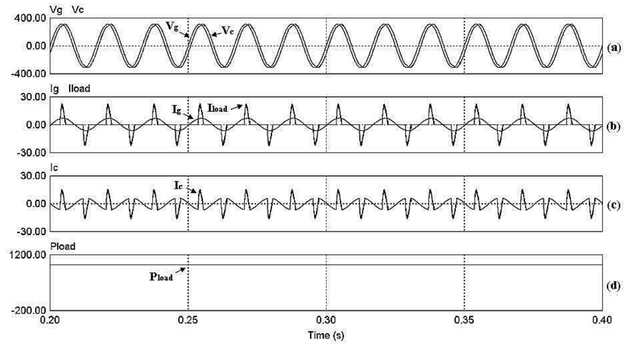

Fig. 3. Waveforms of normal mode at nonlinear load condition.

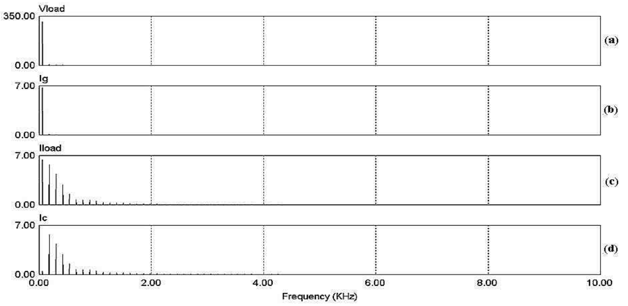

Fig. 4. The harmonic spectrum analysis when normal mode.

The waveform of the charging mode under nonlinear load conditions is shown in Fig. 5. P_g and P_c are the active power waveforms of the grid and the VCVSI, respectively.

Figure 6 and 7 shows the performance of the proposed system during voltage stabilization in the presence of nonlinear load conditions. In this simulation, the grid voltage is changed from its nominal value of 220V to 132V, during voltage sag, and to 308V, during voltage swell. The load voltage is maintained at 220V±1.2% voltage regulation, and is unaffected by the sudden voltage sag and voltage swell.

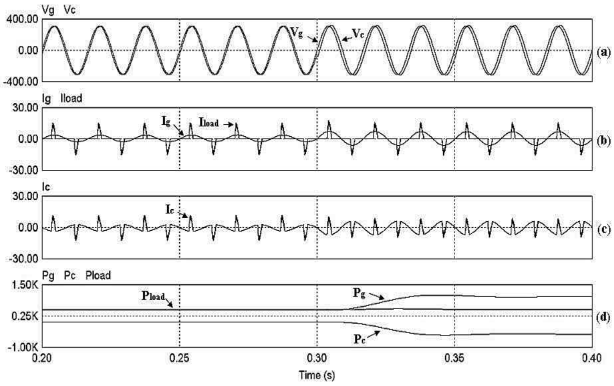

Fig. 5. Waveforms of charging operation mode at nonlinear load condition.

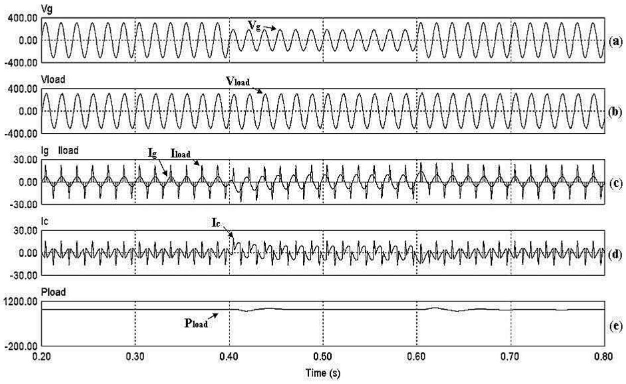

Fig. 6. The operation waveforms of voltage stabilization when voltage sag.

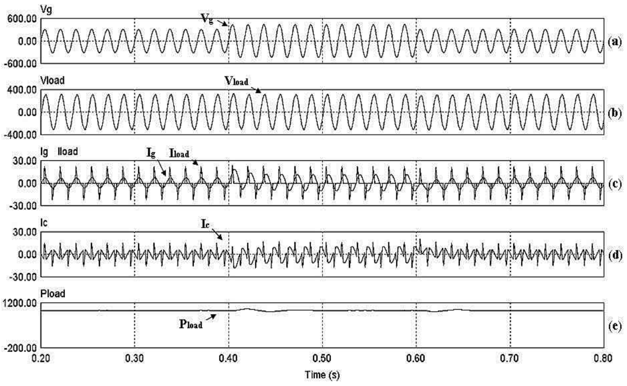

Fig. 7. The operation waveforms of voltage stabilization when voltage swell.

Figure 8 shows that the simulation results in the UPS mode during nonlinear load conditions. It assumes that at 30ms the grid fails and the VCVSI has to supply the load. As shown, before grid failure the system supplies the reactive power demanded by the nonlinear load and rapidly picks up the load after grid failure.

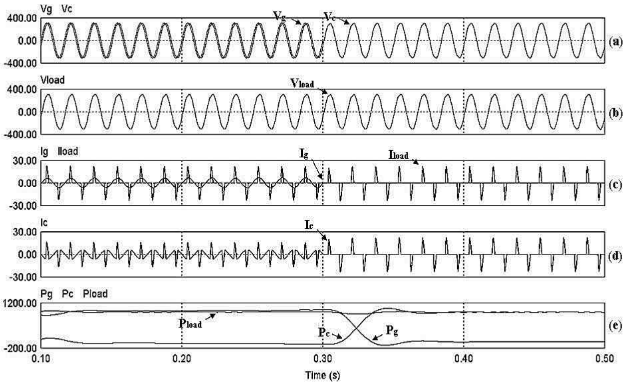

Fig. 8. The operation waveforms of UPS mode for state an transient response at nonlinear load.

4 Conclusion

This paper addressed parallel processing UPS using a single phase bi-directional VCVSI for sudden voltage fluctuation in computer applications. It was demonstrated that the system performs well in either the normal or UPS mode of operation. In the normal mode, the VCVSI operates to compensate the current harmonic and the reactive power demand of nonlinear or variable loads. The system controlled and provided voltage stabilization for the load when sudden voltage sag and swell occurred. In the UPS mode, the proposed system supplied sinusoidal voltage at the fundamental value for the load during an abnormal utility power condition. It was shown that the proposed system protected the system from outages by an abnormal utility power conditions and sudden voltage fluctuations and changes.

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