An Equivalent Load Sharing by Wireless Parallel Operation Control in UPS

Young-Bok Byun, Tae-Geun Koo, Ki-Yeon Joe, Dong-Hee Kim, and Chul-U Kim

Abstract - An equivalent load sharing control based on the frequency and voltage droop concept for parallel operation of two three-phase Uninterruptible Power Supply (UPS) systems with no control interconnection lines is presented in this paper. First of all, due to the use of active power and reactive power as control variables, the characteristics of output powers according to amplitude and phase differences between output voltages of two UPS systems are analyzed. Secondly, simulation results under different line impedance demonstrate the feasibility of the wireless parallel operation control. Finally, experiments are presented to verify the theoretical discussion with two three-phase 20kVA UPS systems employed TMS320C32, a kind of real time digital signal processor (DSP).

Key Words - UPS, Droop method, Wireless parallel operation, Load sharing, DSP.

1. Introduction

Recently computer related equipment has been widely used in various areas. The design criterion of its power supply is stricter than that of general equipment. Thus, a stable and high quality power source is required to ensure that the equipment operates continuously. To supply the clean power, the UPS has become more important in many parts as the power supply system. In order to improve the reliability of the whole system, the demand for the UPS systems connected in parallel is increasing. The parallel operation of the UPS systems has many desirable features such as expandability of output power, ease of maintenance, and redundancy implementation [1]. The technical aspect of the parallel operation is a proper load sharing among the UPS systems. Since the load sharing is very sensitive to discrepancies between components of each UPS system, line impedance imbalance, errors of detection and so on, a proper control is required to share the load equally. The line impedance, from the output terminal of a system to the load, considerably affects the load sharing [2].

The output voltages of all the paralleled systems must be strictly synchronized in frequency, phase and amplitude to guarantee the equality of output power sharing, otherwise the output current may contain reactive circu lar component, i. e., circulating current. This will decrease the capability of the whole power system. Generally, 1-degree difference in phase leads to 50 percent power difference [3-4]. Although many techniques of parallel operation inverters can be found in the literature, most of the techniques normally need auxiliary control interconnection lines to get information such as output frequency and current from other systems [5-6]. However, the control interconnection lines restrict the location of the paralleled systems, cause noise disturbance, and hinder the isolation and redundancy of multi-inverter systems [2].

To operate independently each UPS system in this paper, the load sharing control is adapted to the frequency and voltage droop method[2], and the variation of output power per every sampling time is added it in. The output frequency and voltage droops as function of the active and reactive power respectively, and each UPS system has no interconnection lines except for the power lines. In order to share a load equally, the essential requirements are high precision in detection and control, as well as extremely high speed in calculating. Such being the case, we could found no experimental results on the wireless independent control in the literature.

Thus, this paper proposes the discrete real time calculation method and verifies the wireless load sharing control algorithm through simulation and experiment on two three-phase 20kVA UPS systems. All the control operation are performed by DSP (TMS320C32). Hardware of the whole control system is completely digitalized. Simulation and experimental results show that the control algorithm can achieve an equivalent load sharing and a fast dynamic response.

2. Analysis of Power Sharing

For the analysis of power sharing according to amplitude and phase differences between output voltages, the equivalent circuit of two UPS systems in parallel is shown in Fig.1.

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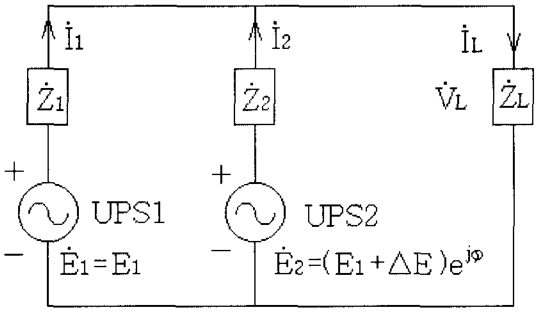


Fig. 1 Equivalent circuit for analysis of power sharing

where $\dot{V}_L$ is the load voltage, $\dot{E}_1$and $\dot{E}_2$ are the output voltages of UPS1 and 2, respectively. $\dot{I}_L$ is the load current. $\dot{I}_1$and $\dot{I}_2$ are the output currents of UPS1 and 2, respectively. $\dot{Z}_L$ is the load impedance, $\dot{Z}_1$and $\dot{Z}_2$ are the line impedance of UPS1 and 2, respectively. ΔE and φ are the amplitude and phase differences between two output voltages, respectively.

When $\dot{Z}= \dot{Z}_1= \dot{Z}_2$, following basic circuit equations can be obtained from Fig. 1.

$$\dot{I}_1=\frac{\dot{E}_1-\dot{V}_L}{\dot{Z}},\quad \dot{I}_2=\frac{\dot{E}_2-\dot{V}_L}{\dot{Z}},\quad \dot{I}_L=\frac{\dot{V}_L}{\dot{Z}_L}$$

$$\dot{V}_L=\dot{E}_1\frac{\dfrac{\dot{Z}\cdot\dot{Z}_L}{\dot{Z}+\dot{Z}_L}}{\dot{Z}+\dfrac{\dot{Z}\cdot\dot{Z}_L}{\dot{Z}+\dot{Z}_L}}+\dot{E}_2\frac{\dfrac{\dot{Z}\cdot\dot{Z}_L}{\dot{Z}+\dot{Z}_L}}{\dot{Z}+\dfrac{\dot{Z}\cdot\dot{Z}_L}{\dot{Z}+\dot{Z}_L}} \tag{1}$$

The equation $\dot{V}_L$ can be simplified as follows:

$$\dot{V}_L=\frac{\dot{E}_1+\dot{E}_2}{1+\dfrac{\dot{Z}+\dot{Z}_L}{\dot{Z}_L}}=\frac{2E_1e^{j\frac{\varphi}{2}}+\Delta Ee^{j\varphi}}{2+\dfrac{\dot{Z}}{\dot{Z}_L}} \tag{2}$$

Thus, using the two equations above, the complex powers $\dot{S}_1$ and $\dot{S}_2$ of two UPS systems are derived as follows:

$$\begin{aligned}\dot{S}_1 &= \dot{V}_L\cdot\dot{I}_1^* = \dot{V}_L\left(\frac{\dot{E}_1-\dot{V}_L}{\dot{Z}}\right)^*\\ &=\frac{2E_1e^{j\frac{\varphi}{2}}+\Delta Ee^{j\varphi}}{\dot{Z}^*(2+\dfrac{\dot{Z}}{\dot{Z}_L})(2+\dfrac{\dot{Z}^*}{\dot{Z}_L^*})}\cdot\\ &\quad\left[E_1\left(2+\frac{\dot{Z}^*}{\dot{Z}_L^*}-2e^{-j\frac{\varphi}{2}}\right)-\Delta Ee^{-j\varphi}\right]\end{aligned} \tag{3}$$

$$\begin{aligned}\dot{S}_2 &= \dot{V}_L\cdot\dot{I}_2^* = \dot{V}_L\left(\frac{\dot{E}_2-\dot{V}_L}{\dot{Z}}\right)^*\\ &=\frac{2E_1e^{j\frac{\varphi}{2}}+\Delta Ee^{j\varphi}}{\dot{Z}^*(2+\dfrac{\dot{Z}}{\dot{Z}_L})(2+\dfrac{\dot{Z}^*}{\dot{Z}_L^*})}\cdot\\ &\quad\left\{E_1\left[\left(2+\frac{\dot{Z}^*}{\dot{Z}_L^*}\right)e^{-j\varphi}-2e^{-j\frac{\varphi}{2}}\right]+\left(1+\frac{\dot{Z}^*}{\dot{Z}_L^*}\right)\Delta Ee^{-j\varphi}\right\}\end{aligned} \tag{4}$$

where $\dot{I}_1^*$, $\dot{I}_2^*$, $\dot{Z}^*$ and $\dot{Z}_L^*$ are the conjugates of $\dot{I}_1$, $\dot{I}_2$, $\dot{Z}$ and $\dot{Z}_L$, respectively.

2.1 ΔE = 0 & φ = 0

Assuming that both amplitude difference ΔE and phase difference φ between two output voltages are zero, that is, the two UPS systems have the same output voltage, the complex powers $\dot{S}_{1,0}$and $\dot{S}_{2,0}$ are equal as follows:

$$\dot{S}_{1,0}=\frac{2E_1^2}{\dot{Z}_L^*(2+\dfrac{\dot{Z}}{\dot{Z}_L})(2+\dfrac{\dot{Z}^*}{\dot{Z}_L^*})} \tag{5}$$

$$\dot{S}_{2,0}=\frac{2E_1^2}{\dot{Z}_L^*(2+\dfrac{\dot{Z}}{\dot{Z}_L})(2+\dfrac{\dot{Z}^*}{\dot{Z}_L^*})} \tag{6}$$

2.2 $\Delta E \neq 0$ & φ = 0

To facilitate the derivation of the relationship between the amplitude difference ΔE and the output power, if φ = 0 in Eq. (3) and (4), the complex powers $\dot{S}_{1,\Delta E}$ and $\dot{S}_{2,\Delta E}$ will be written as follows:

$$\dot{S}_{1,\Delta E}=\frac{2E_1^2}{\dot{Z}_L^*(2+\dfrac{\dot{Z}}{\dot{Z}_L})(2+\dfrac{\dot{Z}^*}{\dot{Z}_L^*})}\left[1+\left(\frac{1}{2}-\frac{\dot{Z}_L^*}{\dot{Z}^*}\right)\frac{\Delta E}{E_1}\right] \tag{7}$$

$$\dot{S}_{2,\Delta E}=\frac{2E_1^2}{\dot{Z}_L^*(2+\dfrac{\dot{Z}}{\dot{Z}_L})(2+\dfrac{\dot{Z}^*}{\dot{Z}_L^*})}\left[1+\left(\frac{3}{2}+\frac{\dot{Z}_L^*}{\dot{Z}^*}\right)\frac{\Delta E}{E_1}\right] \tag{8}$$

For simplifying the analysis, we can assume that $\dot{Z}_L \gg \dot{Z}$ and the line impedance $\dot{Z} = R+jwL$. Thus, the variations of the complex powers $\Delta\dot{S}_{1,\Delta E}$ and $\Delta\dot{S}_{2,\Delta E}$ under the amplitude difference are derived as follows:

$$\begin{aligned}\Delta\dot{S}_{1,\Delta E} &= \dot{S}_{1,\Delta E}-\dot{S}_{1,0}\\ &=-\frac{R\cdot E_1}{2\,|Z|}\cdot\Delta E-j\frac{wL\cdot E_1}{2\,|Z|}\cdot\Delta E\end{aligned} \tag{9}$$

$$\begin{aligned}\Delta \dot{S}_{2,\Delta E} &= \dot{S}_{2,\Delta E} - \dot{S}_{2,0}\\ &= \frac{R \cdot E_1}{2\,|Z|} \cdot \Delta E + j\frac{wL \cdot E_1}{2\,|Z|} \cdot \Delta E\end{aligned} \tag{10}$$

From Eq. (9) and (10), the relationship between the amplitude difference and the active and reactive power of each UPS system is known completely. If the amplitude difference between two output voltages increases, the powers of UPS2 having the higher output voltage of the two are increased too. However, the powers of UPS1 are decreased. Note that the line impedance is dominantly resistive. However, the source impedance(output impedance) of the inverter is highly inductive. Thus the total impedance of the system becomes almost purely inductive [2].

Consequently, when the reactive powers of two UPS systems are different, the amplitudes of the output voltages have to be controlled to eliminate the reactive power imbalance.

2.3 $\Delta E = 0$ & $\varphi \neq 0$

To know the relationship between the phase difference and the output power, if $\Delta E = 0$ in Eq. (3) and (4), the complex powers $\dot{S}_{1,\varphi}$ and $\dot{S}_{2,\varphi}$ will be obtained as follows:

$$\dot{S}_{1,\varphi} = \frac{E_1^2}{2\dot{Z}_L^*(1+\frac{\dot{Z}}{2\,\dot{Z}_L})(1+\frac{\dot{Z}^*}{2\dot{Z}_L^*})} \cdot \left[(1+\frac{2\dot{Z}_L^*}{\dot{Z}^*}) \cdot e^{j\frac{\varphi}{2}} - \frac{2\dot{Z}_L^*}{\dot{Z}^*}\right] \tag{11}$$

$$\dot{S}_{2,\varphi} = \frac{E_1^2}{2\dot{Z}_L^*(1+\frac{\dot{Z}}{2\,\dot{Z}_L})(1+\frac{\dot{Z}^*}{2\dot{Z}_L^*})} \cdot \left[(1+\frac{2\dot{Z}_L^*}{\dot{Z}^*}) \cdot e^{-j\frac{\varphi}{2}} - \frac{2\dot{Z}_L^*}{\dot{Z}^*}\right] \tag{12}$$

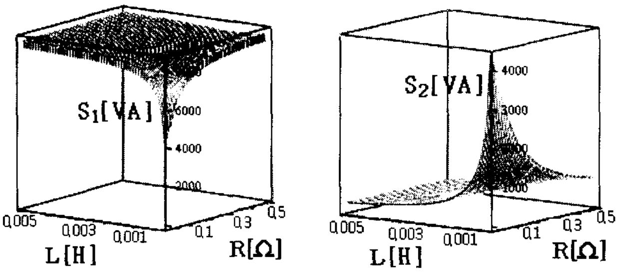
In order to simplify the analysis, assuming that $\dot{Z}_L \gg \dot{Z}$ and the line impedance $\dot{Z} = R + jwL$, the variations of the complex powers $\Delta\,\dot{S}_{1,\varphi}$ and $\Delta\,\dot{S}_{2,\varphi}$ according to the phase difference will be derived as follows:

$$\begin{aligned}\Delta \dot{S}_{1,\varphi} &= \dot{S}_{1,\varphi} - \dot{S}_{1,0}\\ &= -\frac{wL \cdot E_1^2}{2\,|Z|} \cdot \varphi + j\frac{R \cdot E_1^2}{2\,|Z|} \cdot \varphi\end{aligned} \tag{13}$$

$$\begin{aligned}\Delta \dot{S}_{2,\varphi} &= \dot{S}_{2,\varphi} - \dot{S}_{2,0}\\ &= \frac{wL \cdot E_1^2}{2\,|Z|} \cdot \varphi - j\frac{R \cdot E_1^2}{2\,|Z|} \cdot \varphi\end{aligned} \tag{14}$$

In Eq. (13) and (14), we can know the relationship between the phase difference and the active and reactive power of each UPS system. Note that the total impedance of the system is nearly inductive.

Therefore, to ensure an equal active power sharing, if the active powers of UPS systems are different, their phases must be controlled. Especially, owing to the E_1^2 in Eq. (13) and (14), the variation rate of the complex power under the phase difference is very high, so we should control slightly the phase.



(a) (b)

Fig. 2 Complex powers of (a) UPS1 and (b) UPS2 under line impedance imbalance

2.4 Line Impedance Imbalance

The line impedance imbalance considerably impacts the output power sharing. To get the characteristics of the power sharing under the line impedance imbalance, we set the line resistance = 0.01[Ω] and the line inductance = 0.0001[H] of the UPS1, and change the line resistance = 0.01 ~ 0.5[Ω] and the line inductance = 0.0001 ~ 0.005[H] of the UPS2.

As can be seen Fig. 2, the output power is very sensitive to the line impedance imbalance. Therefore, we can know that a proper control is required for compensating the imbalance.

2.5 Circulating Current

Circulating current, which flows from one UPS to another, will increase output currents of both UPS systems and operation loss, and hinder a proper operation.

The circulating current $\dot{I}_c$ is defined as follows:

$$\dot{I}_c = \frac{\dot{I}_1 - \dot{I}_2}{2} \tag{15}$$

The circulation current is caused by the amplitude and phase difference between two output voltages. Fig. 3 shows the circulating current in the case of the amplitude difference ΔE = 0 ~ 2[V] and the phase difference φ = 0 ~ 2[^{0}]. In the figure, we can know that the circulating current increases directly in proportion to the amplitude difference and the phase difference between two output voltages.

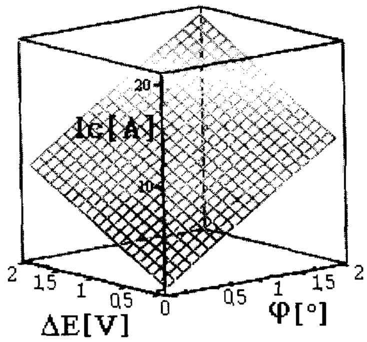


Fig. 3 Circulating current under amplitude differences and phase differences

3. Digital Control Algorithm

3.1 Digital Filter

Ramamoorthy[7] first proposed that the desired fundamental voltage or current should be extracted from the distorted signal by correlating one cycle of data samples with the stored samples of reference fundamental sine and cosine waves. Fig. 4 illustrates the process [8]. With a sampling rage of N samples per *k*th harmonic time period and an observation window of one full cycle, the cross-correlation of the digitized signal *{x(n)}* with cosine and sine waves is expressed as follows:

$$y_{rk}(m) = \frac{2}{N}\sum_{n=0}^{(N-1)} x(m-n)\cos(m-n) \tag{16}$$

$$y_{ik}(m) = \frac{2}{N}\sum_{n=0}^{(N-1)} x(m-n)\sin(m-n) \tag{17}$$

$$y_k(m) = y_{rk}(m) + jy_{ik}(m) \tag{18}$$

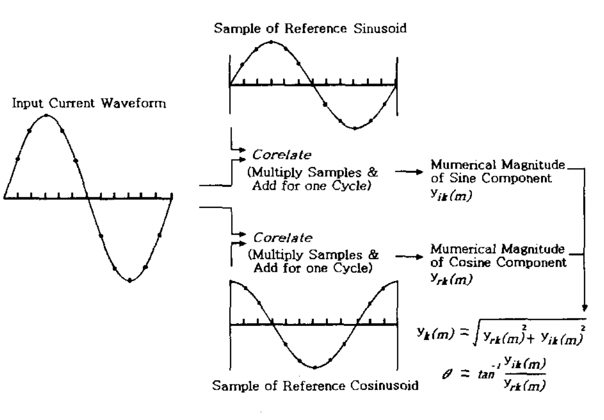


Fig. 4 Fourier notch-filter algorithm

where cos*(m-n)* and sin*(m-n)* are the digital values of the cosine and sine functions of the *k*th harmonic frequency at the *(m-n)*th sampling instant, and the filter outputs $y_{rk}(m)$ and $y_{ik}(m)$ are the real and imaginary components of the fundamental frequency at the *m*th sampling instant.

3.2 Output Power Calculation

To operate independently each UPS system, its three-phase active and reactive powers are required as control variables. Therefore, the real and imaginary components of three-phase voltage and current are needed.

The components can be simply obtained by the digital filter. Thus, active power and reactive power of A-phase out of three-phase can be calculated easily as follows:

* Active power

$$\begin{aligned}
&= V_A \cdot I_A \cos(\theta_v - \theta_i) \\
&= V_A \cdot I_A (\cos\theta_v \cdot \cos\theta_i + \sin\theta_v \cdot \sin\theta_i) \\
&= V_A \cos\theta_v \cdot I_A \cos\theta_i + V_A \sin\theta_v \cdot I_A \sin\theta_i \\
&= (V_r \cdot I_r) + (V_i \cdot I_i)
\end{aligned} \tag{19}$$

* Reactive power

$$\begin{aligned}
&= V_A \cdot I_A \sin(\theta_v - \theta_i) \\
&= V_A \cdot I_A (\sin\theta_v \cdot \cos\theta_i - \cos\theta_v \cdot \sin\theta_i) \\
&= V_A \sin\theta_v \cdot I_A \cos\theta_i - V_A \cos\theta_v \cdot I_A \sin\theta_i \\
&= (V_i \cdot I_r) - (V_r \cdot I_i)
\end{aligned} \tag{20}$$

where V_A and I_A are the rms values of A-phase voltage and current, respectively, θ_v and θ_i are the phase difference between voltage and reference wave forms, and between current and reference wave forms, respectively, V_r, V_i, I_r and I_i are the real and imaginary components of voltage and current, respectively.

3.3 Control Algorithm

The wireless parallel operation control algorithm is adapt-

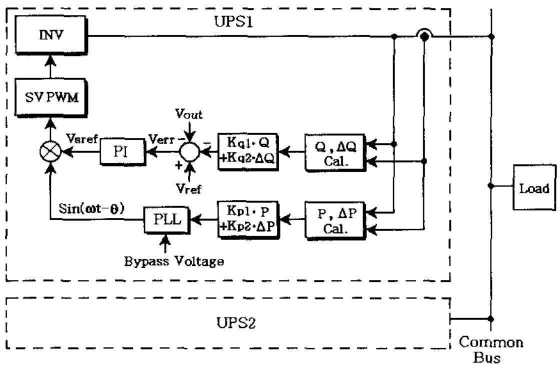


Fig. 5 Configuration of control system

ed to the frequency and voltage droop method added the variation of output power per every sampling time. The output power of each UPS system is calculated by only its output voltage and current.

The configuration of wireless load sharing control is shown in Fig. 5.

The control algorithm of the reactive power is as follows:

$$V_{err} = V_{ref} - V_{out} - K_{q1} \cdot Q - K_{q2} \cdot \Delta Q \tag{21}$$

where Q is the reactive power, ΔQ represents $Q_n - Q_{n-1}$, V_{out} is the output voltage, V_{ref} is the reference voltage, and K_{q1} and K_{q2} are reactive power coefficients. We can derive that the output voltage V_{out} is dropped by Q and ΔQ in Eq. (21). Due to the droop characteristics, in case that the reactive powers of two UPS systems are different while parallel operation, the two output voltages will drop to such values that both systems will be operating in a lower voltage eliminating the reactive power imbalance. The $K_{q2} \cdot \Delta Q$ in Eq. (21) is added to the conventional droop method. It is to minimize the output voltage drop for the transient state, and to get a fast transient response.

The droop method is simple to implement. However, in this case a trade-off must be made between accuracy of reactive power sharing and output voltage quality. The higher the reactive power coefficients the better accuracy of the reactive power sharing. But, higher the coefficients mean a reduction in output voltage quality. As a result, the coefficients should be decided so that the output voltage can be within a permission range.

The control algorithm of the active power is as follows:

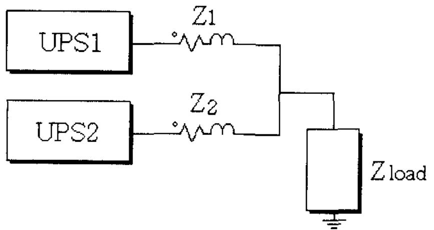
$$f_n = f_{n-1} - K_{p1} \cdot P - K_{p2} \cdot \Delta P \tag{22}$$

where P is the active power, ΔP represents $P_n -$, P_{n-1}, f_n is the reference frequency, K_{p1} and K_{p2} are the active power coefficients.

Generally, the frequency difference creates the phase difference. In Eq. (22), the difference of the active powers of two UPS systems in parallel causes the phase difference between two output voltages. Hence, the active power sharing can be controlled by the phase of output voltage slightly varied from that of the bypass voltage. Also there is a trade-off between accuracy of active power sharing and phase synchronization. Thus, the active power coefficient should be decided carefully.

4. Simulation

For the simulation studies, the general - purpose simulation package PSIM was used. As shown in Fig. 6, to prove the validity of the control algorithm, two UPS systems in parallel are composed with different line impedance.



$$Z_1 = 0.1 + j0.038[\Omega],\ Z_2 = 0.2 + j0.075[\Omega],$$
$$Z_{load} = 13 + j9.7[\Omega]$$

Fig. 6 Configuration of the simulated system

In Fig. 7, the simulation wave forms of the load voltage and load current, and the output currents for the steady state are illustrated. It can be observed from Fig. 7 that equal current distribution can be achieved regardless of line impedance imbalance, Z_2 is twice as much as Z_1.

To see the characteristics of transient response and power sharing, the simulation results of the active and reactive power, and the output currents are shown in Fig. 8 when the initial load impedance $13 + j9.7[\Omega]$ is stepped down to $6.5 + j4.85[\Omega]$ at 0.25 sec. In this figure, the transient response is quite fast, and the active power is equally shared between two systems while the reactive power sharing is slightly different. The reason for this discrepancy is the line impedance imbalance.

In Fig. 9, the simulation results for two parallel UPS systems of different power ratings are shown. The power coefficients $K_{p1,p2}$ and $K_{q1,q2}$ of each system are set differently. As can be seen from Fig. 9, the active and reactive power sharing can be controlled by the power coefficients.

From the simulation results above, the validity of the control algorithm is proved.

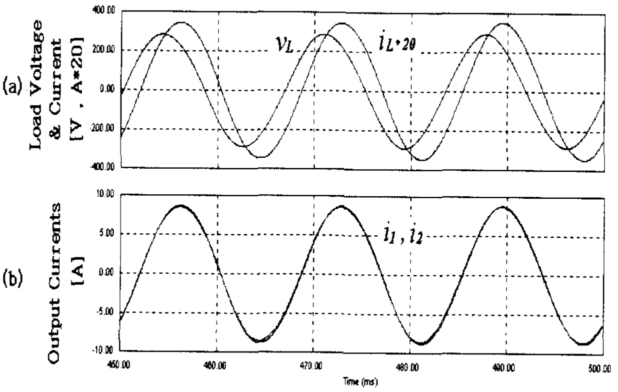


Fig. 7 The simulation wave forms of (a) the load voltage v_L and the load current i_L, and (b) the output currents i_1 and i_2 for the steady state

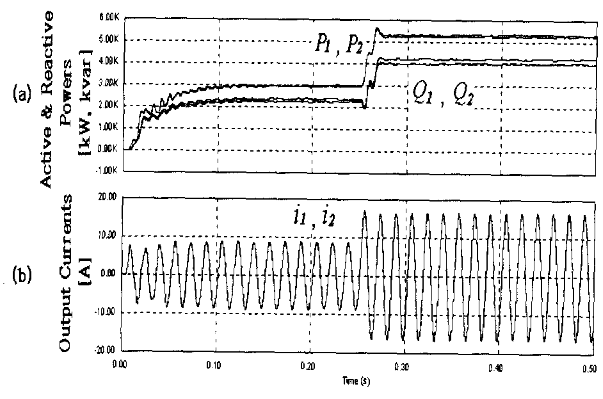


Fig. 8 The simulation results of (a) the active powers P_1 and P_2, reactive powers Q_1 and Q_2, and (b) the output currents i_1 and i_2 with the step load variation

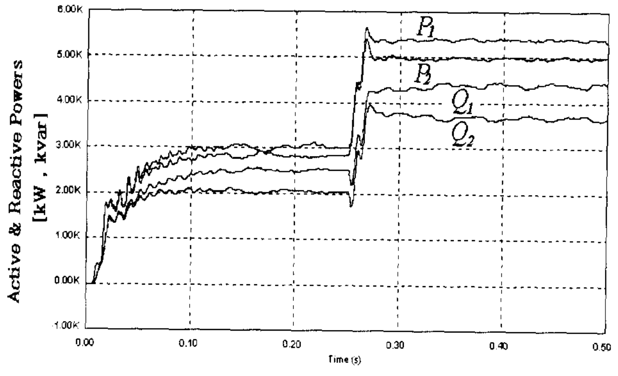


Fig. 9 The simulation results of active powers P_1 and P_2, and reactive powers Q_1 and Q_2 in case that the power coefficients of each UPS system set differently

5. Experimental Results

Two UPS systems have been designed and implemented. The parameters of each system are listed below:

Each system capacity: 20[kVA]
Switching frequency: 5.16[kHz]
DC Link voltage: 265[V]
Output voltage: 3ϕ 380[V] / 220[V], 60[Hz]
LC filters: 1.5[mH], 400[μF]

The parallel operation control system has been employed a full digital structure with a 32 bits floating-pointed DSP chip (TMS320C32-50) to fit for the real time control, the reliability of signal transmission, and the fast and complicate calculation.

Fig. 10 shows the experimental wave forms of the load voltage and load current, and the output currents with no load. The output current, circulating current, are quite small. Thus, the parallel operation is quite stable at no load.

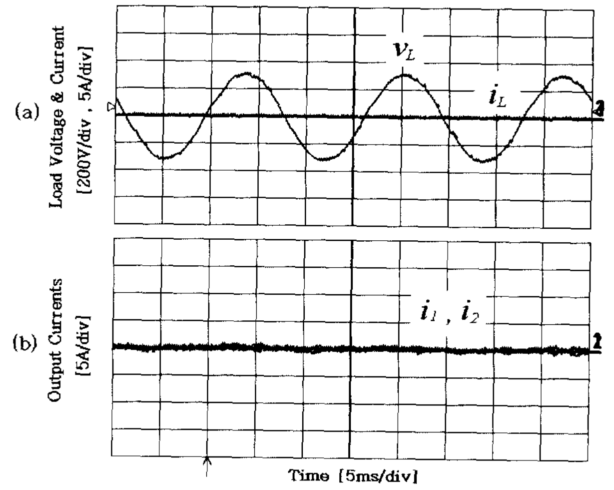


Fig. 10 The experimental wave forms of (a) the load voltage v_L and the load current i_L, and (b) the output currents i_1 and i_2 with no load

Fig. 11 illustrates the experimental wave forms of the load voltage and current, and the output currents for the steady state when a power factor, a resistant load = 7.2[kW] and a reactant load = 5.4[kVar], is 0.8. In this figure, the experimental wave forms are perfectly the same as those of simulation in Fig. 7.

Fig. 12 shows the experimental results of the active powers and the output currents when a pure resistant load changes from no load to 7.2[kW], and then to 14.4[kW]. It can be observed from Fig. 12 that a fast transient response

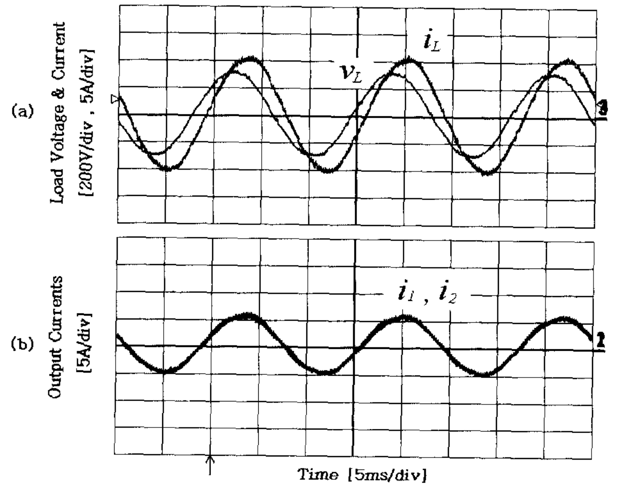


Fig. 11 The experimental wave forms of (a) the load voltage v_L and the load current i_L, and (b) the output current i_1 and i_2 for Steady state when the power factor is 0.8

and an equivalent active power sharing like the simulation results in Fig. 8.

Fig. 13 illustrates the experimental results of the active and reactive power when both a resistant load 7.2[kW] and a reactant load 5.4[kVar] are connected, and disconnected to the two UPS systems. The transient response of the reactive power sharing is not so fast. However, totally the error of the power sharing is within 5 percentages at steady state.

The experiment results above also show the validity of the control algorithm.

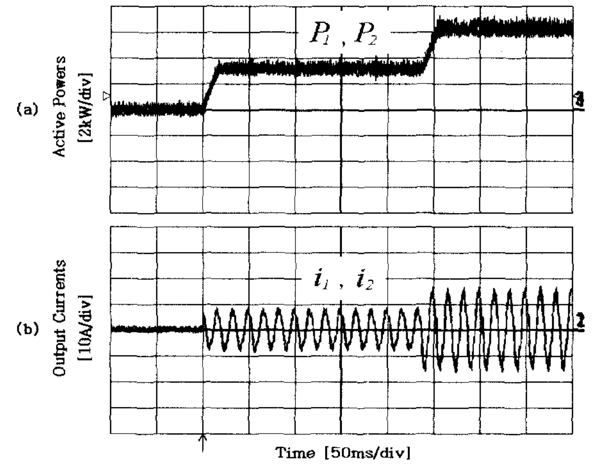


Fig. 12 The experimental wave forms illustrating the effects of the step load variation. (a) the active powers P_1 and P_2, and (b) the output currents i_1 and i_2

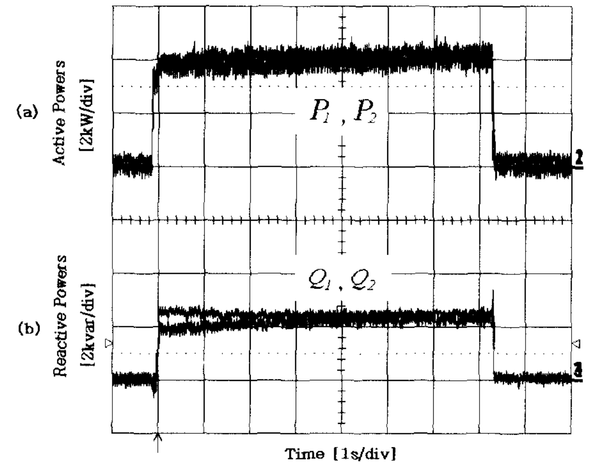


Fig. 13 The experimental results when load is connected and disconnected. (a) the active powers P_1 and P_2, and (b) the reactive powers Q_1 and Q_2

6. Conclusion

The parallel operation control algorithm with no control interconnection lines has been studied. The control algorithm has been achieved simulation and experiment, and showed that an equivalent load sharing. The key findings of this paper can be summarized as follows:

- The characteristics of the active and reactive power of each system under amplitude and phase difference between two output voltages have been analyzed.
- The characteristics of the power sharing under the line impedance imbalance have been illustrated.
- A good performance of the control algorithm has been proved by simulation and experiment on two 20kVA UPS systems that employed a 32 bits floating-pointed DSP chip.
- Totally, the error of power sharing is within 5 percentages at steady state.

In the next future, we plan to implement this control algorithm on nonlinear loads in various operating conditions.

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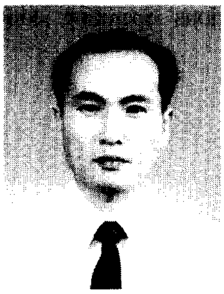

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