Review on: To Optimize the Reduction of THD of Line Interactive UPS System with SRF Controller in 3 Phase 4 Wire System

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Abstract: In this review paper author shows a three-phase line-interactive uninterruptible power supply (UPS) system along with the series-parallel power-line conditioning capabilities. In this system for harmonic and reactive power compensation author used Synchronous reference frame (SRF)-based controller that can be generated from any configuration of non-linear loads. General line conditions UPS system works on the principal of compensating the input currents and output voltages. Here author introduce a new technology which consist of two three-phase pulse width modulation (PWM) converters. First called series active filters and second called parallel active filters. This two are used to perform the series and parallel active power-line compensation. The series active filter works as sinusoidal current source in phase with the input voltage, drawing from utility sinusoidal and balanced input currents with low total harmonic distortion (THD). The parallel active filter works as sinusoidal voltage source in phase with the input voltage, providing regulated and sinusoidal output voltages with low THD.

Index Terms - total harmonic distortion (THD), Synchronous reference frame (SRF), line-interactive UPS.

I. INTRODUCTION

The use of non-linear loads such as, personal computers, UPS, etc. has been rapidly increase in the last few decades. This also creates problem of power supply to such systems. The non-linear load generates harmonic currents that reduce the power factor and to increase the total harmonic distortion (THD) in input voltages. Here the problem is even bigger when single-phase nonlinear loads are connected in three-phase, four-wire systems because the phase currents are not sinusoidal, apart from that perfectly balanced single-phase loads results in significant neutral currents and their amplitude can exceed the amplitude of the line currents (Gruzs, 1990). When the non-linear loads are unbalanced, the input currents also are unbalanced and its multiples will flow in the neutral wire. This neutral wire current can cause damage to both neutral conductor and the transformer to which it is connected (Quinn *et al*., 1992). To overcome from this drawback a active filter topologies has been used to compensate neutral harmonic currents (Quinn *et al*., 1992; Quinn *et al*., 1993; Thomas *el al*., 1996). A new technological good quality power supply system is introduce called as Uninterruptible power supply (UPS) which provides clean and uninterruptible power to critical loads such as industrial process controls, computers, medical equipment, data communication systems, and protection against power supply disturbances or interruptions (Oliveira da Silva *et al*., 2001; Kamran *et al*., 1995; Jeon *et al*., 1997, Cheung *et al*., 1996; Lin *et al*., 1993). In (Lin *et al*., 1993).

In this paper a three phase parallel processing UPS has been presented with harmonic and reactive power compensation, but the output voltages and the input currents cannot be controlled simultaneously. Three-phase UPS systems with series-parallel active power-line conditioning have been proposed using different control strategies (Oliveira da Silva *et al*., 2001; Kamran *et al*., 1995). In (Kamran *et al*., 1995) the three-phase UPS system was employed for three-wire systems, and in (Oliveira da Silva *et al*., 2001), albeit it can be employed for three-wire and four-wire systems, the UPS was used to feed a non-linear load composed by a three phase non-controlled rectifier, in which neutral currents do not exist.

This paper presents a three-phase line-interactive UPS system with active series-parallel power-line conditioning capabilities using an SRF-based controller, for three-wire and four-wire systems in which three single-phase loads are fed. In UPS standby operation mode, the series active power filter acts as a sinusoidal current source and the parallel active power filter acts as a sinusoidal voltage source (Oliveira da Silva *et al*., 2001). The output voltages are controlled to have constant rms values and low THD and the source currents are controlled to be sinusoidal and balanced with low THD. Both input currents and output voltages are simultaneously controlled to be in phase with respect the input voltages. Therefore, an effective power factor correction is carried out. The control algorithm using SRF method and the active power flow through the UPS system are described and analytically studied.

II. EXISTING SYSTEM

The topology of the line-interactive UPS system is shown in Fig. 1. Here two pulse width modulation (PWM) converters, coupled to a common dc-bus, are used to perform the series active filter and the parallel active filter functions. Capacitors and a battery bank are placed in the dc-bus and a static switch 'sw' is used to provide the disconnection between the UPS system and the power supply when an occasional interruption of the incoming power occurs. The center-tap of the dc-bus is connected to the utility neutral.

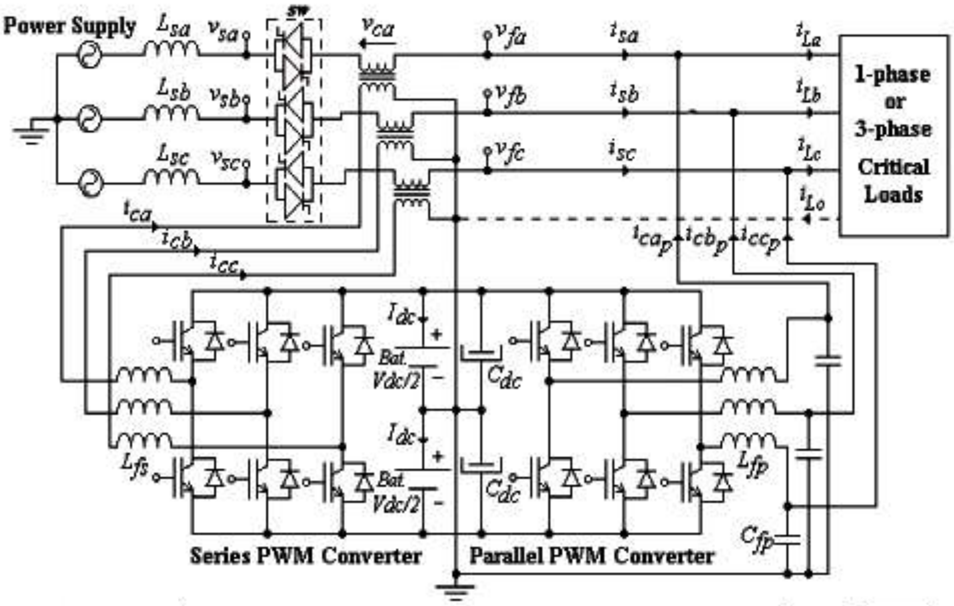

Figure 1. Line-Interactive UPS system topology

II.I SYNCHRONOUS REFERENCE FRAME
Current SRF-Based Controller (Standby Mode)

The use of SRF-based controller is to control the compensating reference currents (i_{ca}^*, i_{cb}^*, and i_{cc}^*) for the series PWM converter as shown in Fig. 1. The block diagram of the control scheme for current compensation is shown in Fig. 2. The three-phase load currents (i_{La}, i_{Lb}, i_{Lc}) are measured and transformed into a two-phase stationary reference frame $(dq)^s$ quantities (id^s, iq^s) based on the transformation (1). Then, these quantities are transformed from a two-phase stationary reference frame $(dq)^s$ into a two-phase synchronous rotating $(dq)^e$reference frame, based on the transformation (2), where $\Theta = \omega t$, is the angular position of the reference frame. The unit vectors $sin\Theta$ and $cos\Theta$ are obtained from PLL system. The currents at the fundamental frequency ω (id^e and iq^e) are now dc values and all the harmonics, transformed into non-dc quantities, can be filtered using a low pass filter (LPF) as shown in Fig. 2. Now, id_{dc}^e represents the fundamental active component of the load current and iq_{dc}^erepresents the fundamental reactive component of the load current, both in *dq* axis.

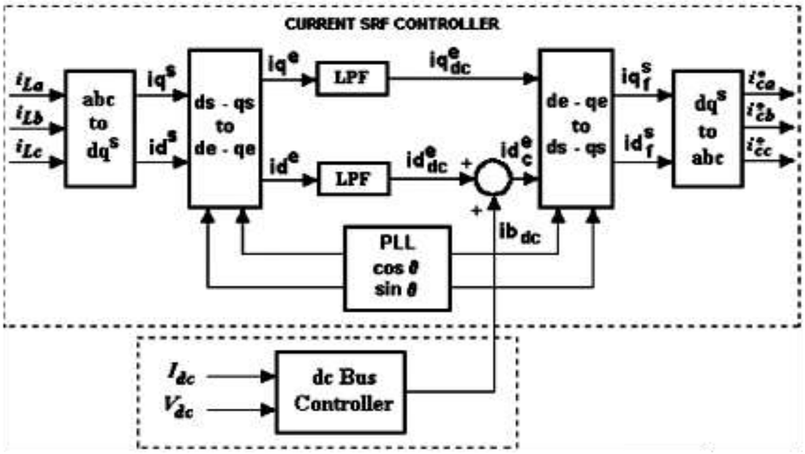

Figure 2. Block diagram of the current SRF-based controller.

An additional dc-bus controller is responsible for regulating the current I_{dc} and the voltage V_{dc} . Apart from the conventional active filter applications, in which only the dc-bus voltage is controlled, the UPS dc-bus controller is able to control the dc-bus current for adequate charging of the battery bank. The dc-bus controller is also responsible to control the active power flow of the UPS system. Its output ib_{dc} is added to the active current in the *d* axis id_{dc}^e as given by (3) and, thus, the amplitude of the reference currents can be controlled by id_c^e .

$$\begin{bmatrix} id^s \\ iq^s \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} id^e \\ iq^e \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} id^s \\ iq^s \end{bmatrix} \quad (2)$$

$$id_c^e = id_{dc}^e + ib_{dc} \quad (3)$$

Now, the dc components of the synchronous reference frame id_c^e and iq_{dc}^e can be transformed into the stationary reference frame $(dq)^s$. The inverse transformation matrix from two-phase synchronous reference frame to two-phase stationary reference frame is given by (4). As only the fundamental active component reference needs to be obtained, (4) can be replaced by (5). The matrix that provides the linear transformation from two-phase system to three-phase stationary reference frame system is given by (6). Thereby, the dc component of the synchronous reference frame id_c^e is transformed into the stationary reference frame $(dq)^s$ and yields the fundamental components of the load currents (i_{ca}^*, i_{cb}^*, and i_{cc}^*). Such reference currents are generated in software.

$$\begin{bmatrix} id_f^s \\ iq_f^s \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} id_{dc}^e \\ iq_{dc}^e \end{bmatrix} \qquad (4)$$

$$\begin{bmatrix} id_f^s \\ iq_f^s \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} id_{dc}^e \\ 0 \end{bmatrix} \qquad (5)$$

$$\begin{bmatrix} i_{ca}^* \\ i_{cb}^* \\ i_{cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} id_f^s \\ iq_f^s \end{bmatrix} \qquad (6)$$

III. PROPOSED SYSTEM

Fig. 3 shows overall scheme of the three-phase line-interactive UPS system. To verify the performance of the three-phase line-interactive UPS system, a prototype was developed and tested. Three single-phase non-linear loads with high load current THD are used to test the line interactive UPS system. The parameters used in the prototype are: Lfp= 300μH, Lfs= 1.4mH, Cfp= 130μF, RLa= 62 Ω, RLb= 55 Ω, RLc= 70 Ω, $C_{La,b,c}$= 470μF, nominal rms line-to-neutral input voltages - $V_{sa,b,c}$= 120V, nominal rms line-to-neutral output voltages - $V_{fa,b,c}$= 115V and dc-bus voltage - V_{dc}= 570V. The apparent power rates of the unbalance loads are: Sa= 560 VA, Sb= 630 VA, and Sc= 540 VA. The part of the scheme shown in the shaded area uses a 400MHz PC computer, a 12 bits resolution data acquisition system and a 12 bits resolution D/A converter board. Both current SRF controller and PLL system (Fig. 2) are implemented in software and are responsible to generate the current and voltage references for the current and voltage analog controllers. Both data acquisition systems and digital controllers run at 5kHz frequency. Output voltages is given by ($v_{fa,b,c}$) and load currents is given by ($i_{La,b,c}$). Despite of the load current THD to be approximately 100% the THD of the regulated and balanced output voltages is less than 4%.

The main advantage of the line-interactive UPS topology, when compared to the on-line topology, which uses two cascaded PWM power converters working at full power rating, is the smaller power rating handled by both series and parallel converters during the standby mode, increasing the efficiency of the UPS. The high series impedance and the low parallel impedance can protect the load against mains transients.

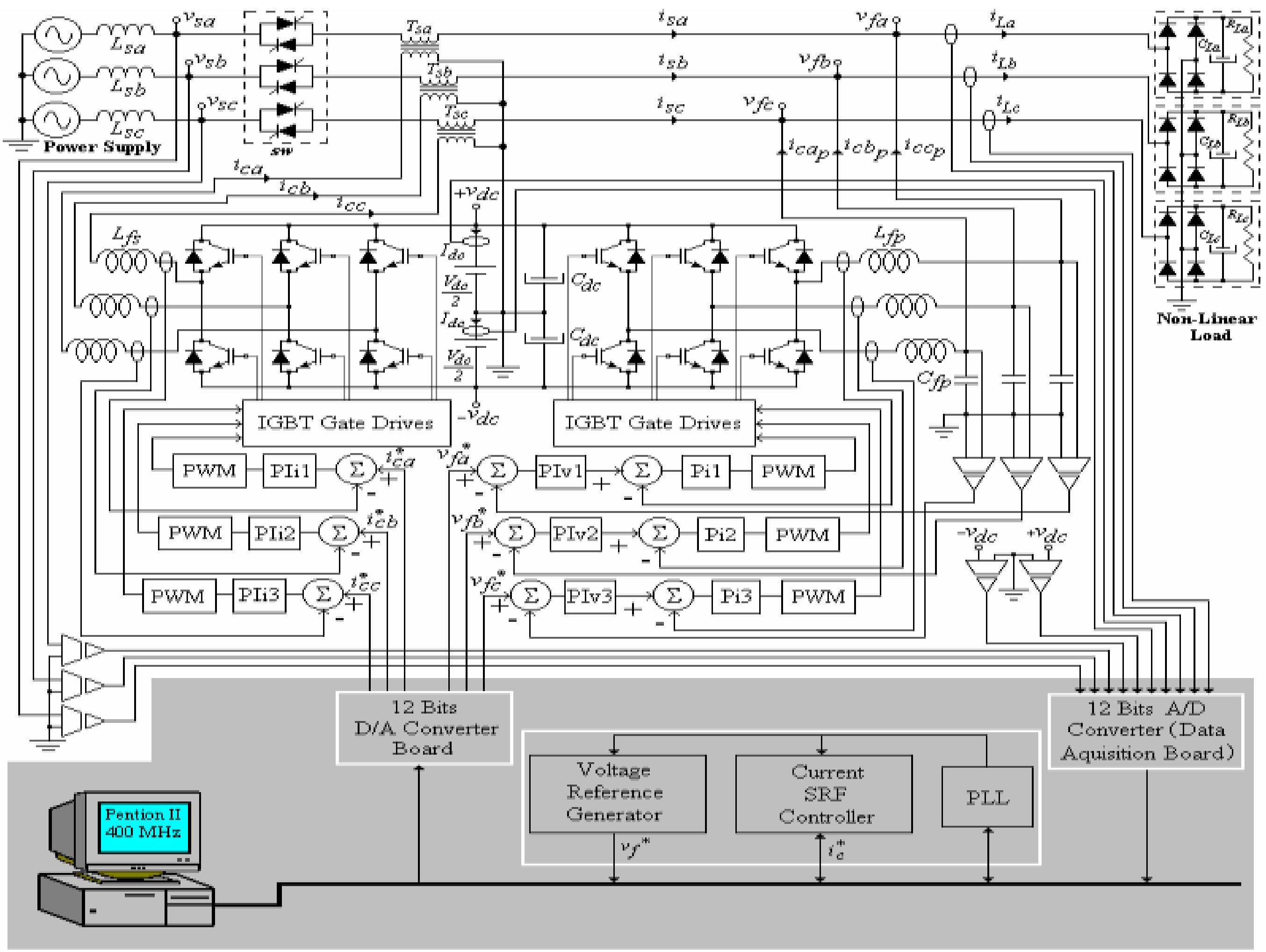

Figure 3

IV. CONCLUSIONS

In this paper three-phase line-interactive UPS system topology with active series-parallel power-line conditioning capabilities has been reviewed for four-wire systems. Drawback of SRF-based controller implementation is that balanced and almost sinusoidal input currents with low THD were obtained. The levels of both fundamental and harmonic contents of the utility neutral current have been reduced considerably. The output voltages are balanced and almost sinusoidal with low THD. To overcome from this line-interactive UPS is presented which uses two cascaded PWM power converters working at full power rating, is the smaller power rating handled by both series and parallel converters during the standby mode, increasing the efficiency of the UPS. The high series impedance and the low parallel impedance can protect the load against mains transients.

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