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Electric Power Systems Research 70 (2004) 1–6
ELECTRIC POWER SYSTEMS RESEARCH
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A new control algorithm of active power line conditioner for improving power quality

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Received 2 September 2002; accepted 6 October 2003

Abstract

In this paper, a new control algorithm for active power line conditioner (APLC) is proposed. The proposed APLC contains two power converters, a series power converter and a shunt power converter. The series power converter is operated as a current source, and it has the function of a harmonic isolation to block the harmonic current from the nonlinear load to mains and the harmonic voltage from the mains to load. The shunt power converter is operated as a voltage source to supply a clean and regulated output voltage to the load. Both power converters use the same dc bus. To demonstrate its performance, a prototype is developed and tested. The tested results show that the proposed APLC has the expected performance.

Keywords: Algorithm; APLC; Shunt

1. Introduction

The problems of power quality such as undervoltage, overvoltage, voltage spike, voltage sag, voltage dip, voltage distortion and short-term outage, have brought more concerns to electric utilities and customers. Computers are widely applied in data processing center, medical equipment and automated manufacturing system. However, the performance of the above equipment is very sensitive to the power quality. The poor power quality may result in the abnormal operation of the above equipment even industry accidents. Every year, the serious cost is paid due to the malfunction of the above equipment [1]. Hence, power supply with high power quality has become more important to ensure the above sensitive equipment to be operated smoothly.

For solving the problems of power quality, many power electronics-based techniques, also known as active power line conditioner (APLC), have been proposed [2–11]. The active power filter is shunt with load to suppress the harmonic current and improve the power factor [2–4]. However, it cannot improve the voltage quality of load side; such as voltage variation, voltage dip, voltage sag and voltage distortion. The dynamic voltage regulator is connected in series with the load to improve the voltage quality of load side [5,6]. Unfortunately, it cannot solve the problems of input harmonic current and input power factor. Hence, the conventional APLC with single power stage cannot solve the power quality problems of both load side and mains side simultaneously.

The uninterruptible power supply (UPS) is used to supply the high quality power to the sensitive load [7,8]. Conventional UPS contains two power conversion stages not only for the on-line UPS but also for the off-line UPS. For an on-line UPS, the ac/dc power converter is used to charge the battery set and supply the dc power to the dc/ac inverter. The dc/ac inverter is used to supply a high quality ac power. The problem of serious input current harmonic and poor input power factor of ac/dc converter can be improved by using advanced power electronic techniques [7,8], and the voltage quality of load side is always better than the input voltage except the inverter is failed. The power capacity of both power conversion stages must match to the load. Therefore,

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doi:10.1016/j.epsr.2003.10.010

the conversion power of on-line UPS is large, and it will degrade the efficiency. For an off-line UPS, it also consists of two power conversion stages, ac/dc charger and dc/ac inverter. The ac/dc charger is used to charge the battery set under normal mains, and the dc/ac inverter is used to convert the dc battery power to ac power under abnormal mains. In general, the power capacity of ac/dc converter (charger) is much smaller than that of on-line UPS. In general, it is not more than 30% of the inverter capacity. However, the load is directly connected to the mains under normal mains, hence, the voltage quality of load side is dependent on the mains. It means that off-line UPS is only used to solve the problem of power outage.

Recently, a new topology of APLC, combining the series and shunt power converters, is proposed [9–11]. The dc terminals of both power converters are connected together. It can also be divided into two topologies, named as long-shunted type and short-shunted type, and shown in Fig. 1. For the long-shunted APLC, the series power converter is connected in series with the load through a series inserted transformer, and the shunt power converter is connected in shunt with the mains. For the short-shunted APLC, the shunt power converter is connected in shunt with the load, and the series power converter is connected in series with the mains through a series inserted transformer. Both of these two types APLC have the performance of supplying high voltage quality to the load and improving the problems of serious input current harmonic and poor input power factor from the load. The overall conversion power of power stages is smaller than that of on-line UPS, and it means that the efficiency of these two types of APLC is raised.

In this paper, a new control algorithm for APLC is proposed. The proposed APLC uses a series power converter and a shunt power converter. This APLC has the performance of harmonic isolation, reactive power compensation and output voltage regulation. The proposed APLC is a short-shunted APLC. The series power converter of proposed APLC is operated as a sinusoidal current source, and it has the function of harmonic isolation to isolate the harmonic flow between the mains and load. The shunt power converter of proposed APLC is operated as a sinusoidal voltage source, and it supplies a clean and regulated output voltage to the load, besides, it can sink the harmonic current of load. Finally, a prototype is developed to verify its performance.

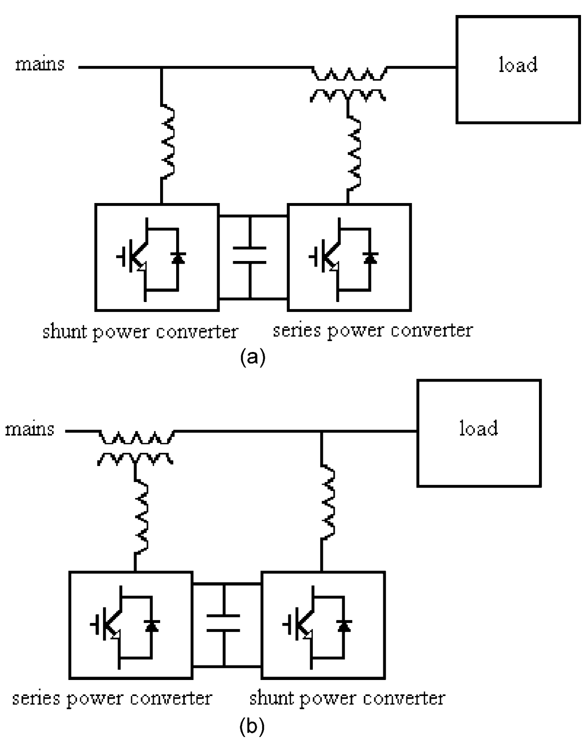

Fig. 1. The combined power converters system, (a) long-shunted type, (b) short-shunted type.

2. Operation theory

For a short-shunted APLC shown in Fig. 1(b), the series power converter is connected in series with the mains. The mains current is desired to be sinusoidal and in phase with the mains voltage to obtain unity input power factor. The current mode control is used to control the series power converter. It can force the mains current to be sinusoidal and in phase with the mains voltage. Hence, the harmonic current of nonlinear load is isolated and unity power factor is obtained. If the mains voltage is sinusoidal and represented as:

$$v_s(t) = V_s \sin(\omega t) \tag{1}$$

The mains current is expected to be

$$i_s(t) = I_s \sin(\omega t) \tag{2}$$

The amplitude of mains current, I_s, is used to determine the real power supplied from the mains side.

The shunt power converter is operated as a voltage source converter. This power converter supplies a sinusoidal voltage with constant amplitude and low total harmonic distortion (THD). Hence, the proposed APLC can be simplified as Fig. 2. From Fig. 2, it can be found that the voltage across the series power converter is the difference voltage between the mains and the output voltage of the shunt power converter. From the viewpoint of vector operation, it can be

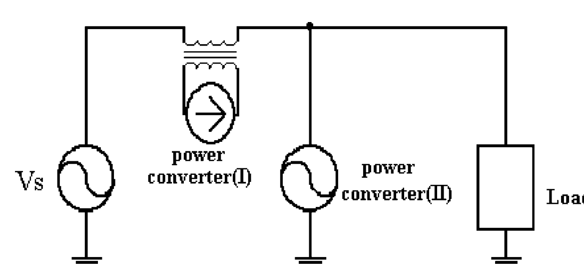

Fig. 2. The equivalent circuit.