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A Novel Hybrid Power Conditioner for Power Quality Enhancement in Four Wire Distribution System



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ABSTRACT:

In this paper, a new hybrid power conditioner is proposed for suppressing harmonic currents and neutral-line currentin three-phase four-wire distribution power systems. The proposedhybrid power conditioner is composed of a neutral-line current attenuatorand a hybrid power filter. The hybrid power filter, configured by a three-phase power converter and a three-phase tunedpower filter, is utilized to filter the nonzero-sequence harmonic currentsin the three-phase four-wire distribution power system. The three-phase power converter is connected to the inductors of the three-phase tuned power filter in parallel, and its power rating canthus be reduced effectively. The tuned frequency of the three-phase tuned power filter is set at the fifth harmonic frequency. The neutral-line current suppressor is connected between the power capacitorsof the three-phase tuned power filter and the neutral lineto suppress the neutral-line current in the three-phase four-wiredistribution power system.With the major fundamental voltage ofthe utility dropping across the power capacitors of the three-phasetuned power filter, the power rating of the neutral-line current suppressorcan thus be reduced. Hence, the proposed hybrid powerconditioner can effectively reduce the power rating of passive and active elements.

Index Terms:
Harmonic, neutral-line current, power converter.

I. INTRODUCTION:

In today‘s environment, electronic loads are very sensitive to harmonics, sags, swells and other disturbances. Among these parameters, current harmonics have become a growing power quality concern.

One more power quality issue is reactive power compensation. Reactive power is required to maintain the voltage to deliver active power. When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines. Though reactive power is needed to run many electrical devices, it can cause harmful effects on electrical appliances. So the reactive power compensation is very important in electrical power system. So, power quality become important in the power system. In the mid-1940s, passive power filters (PPFs) have been widely used to suppress current harmonics and compensate reactive power in distribution power systems [1] due to their low cost, simplicity, and high-efficiency characteristics. But, PPFs have many disadvantages such as low dynamic performance, resonance problems, and filtering characteristics that are easily affected by small variations of the system parameters [2]–[7].

Since the concept of an ―active ac power filter‖ was first developed in 1976 [1], [5], research studies on active power filters (APFs) for current quality compensation are getting more and more attention. APFs can overcome the disadvantages in PPFs, but their initial and operational costs are relatively high [2]–[6] because the dc- link operating voltage should be higher than the system voltage. This slows down their large scale application in distribution networks. In addition, different hybrid active power filter (HAPF) topologies composed of active and passive components in series and/or parallel have been proposed, aiming to improve the compensation characteristics of PPFs and reduce the voltage and/or current ratings (costs) of the APFs, thus leading to improvements in cost and performance [2]–[13]. The HAPF topologies in [2]–[8] consist of many passive components, such as transformers, capacitors, reactors, and resistors, thus increasing the size and cost of the whole system.

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Conventionally, passive power filters have been employedto solve the problems of harmonic currents and neutral-linecurrent in three-phase four-wire distribution power systems.Although passive power filters have the advantage of lowhardware cost, their performance is often significantly affectedby the system impedance.

Furthermore, salientproblems, includinglarge volume, parallel resonance, and series resonancemay further offset the benefits of this method [9], [10]. Withadvances in power semiconductor technology, power-electronic-based active power equipment is gradually replacing orsharing the role of passive power equipment.

II.PROPOSED SYSTEM:

II. THREE-PHASE FOUR-WIRE HYBRID POWER FILTER:

The zig-zag transformer, connected to the load in parallel, hasbeen employed to attenuate the neutral-line current [1], [3], [4].However, the attenuation of neutral-line current is dependenton the ratio between the impedance of the utility system and thezig-zag transformer. Furthermore, the zig-zag transformer alsohas a low impedance path for zero-sequence voltage of the unbalanced utility, which will further cause a significant neutralline current [4].

A single-phase power converter can be combinedwith the zig-zag transformer to advance the performance of the neutral-line current suppression [5], [6]. The single-phase power converter is inserted at the neutral line between the loadand the utility, thus causing fluctuation in the ground voltage ofthe load.

A neutral-current suppression scheme, configured by a-Y transformer and a single-phase power converter connectedin series, is connected to the load in parallel to suppress the neutral-line current [7]. The neutral line of the load is directly connected to that of the utility, and the fluctuation in ground voltage of the load can thus be avoided.

A series of active power filters connected to the neutral line between the utility and the load can suppress the neutral-line current, thus eliminating the needof the transformer for a zero current path [8]. However, there is fluctuation in ground voltage of the load because the neutral lines of the load and utility are separated.

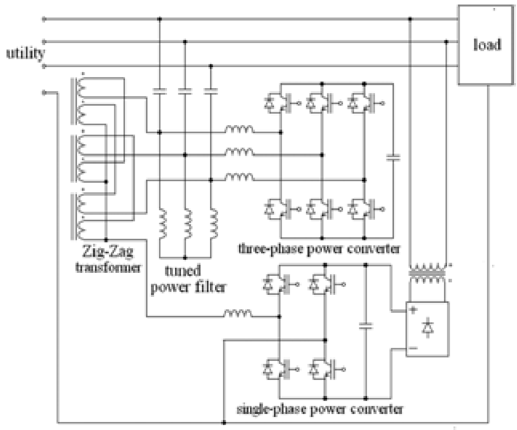

Fig. 1. System configuration of the proposed hybrid power conditioner

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A new hybrid power conditioner for solving the problems of harmonic currents and neutral-line current in three-phase fourwire distribution power systems is proposed in this paper. This hybrid power conditioner is configured by a neutral-line currentattenuator and a hybrid power filter. The hybrid powerfilter, configured by a three-phase power converter and a threephase tuned power filter, is utilized to filter the nonzero-sequence harmonic currents in the three-phase four-wire distributionpower system. The neutral-line current suppressor is connected between the power capacitors of the three-phase tuned power filter and the neutral line to attenuate the neutral-line current in the three-phase four-wire distribution power system. The proposed hybrid power conditioner can effectively reduce thepower rating of passive and active elements.

III.CONTROL STRATEGY

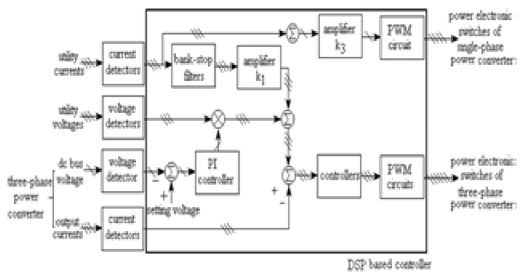

Fig. 3. Control block diagram of the three-phase and single-phase power converters.

Fig. 3shows the control block diagram of three-phase and single-phase power converters. The three-phase power converter adopts the current-mode control.

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The current referencesshould be calculated first. The current references should beequal to (1)–(3), and they contain a fundamental signal and a harmonic signal. The detected three-phase utility currents are sent to the bandstop filters to extract their harmonic components.The outputs of the bandstop filters are sent to the amplifier with gain , and the harmonic signals of the currentreferences are then obtained. The detected dc bus voltage ofthe three-phase power converter is compared with the settingvoltage, and the compared result is sent to a proportional-integral(PI) controller. The output of the PI controller is . Boththe outputs of the PI controller and the detected three-phaseutility voltages are sent to the multipliers so that the fundamental signals of the current references are obtained. Thecurrent references are obtained by summing up the harmonicsignals and the fundamental signals.

The detected output currentsof the three-phase power converter are compared with thecurrent references, and the compared results are then sent to thecontrollers. The outputs of the controllers are sent to the PWM circuits to generate the driver signals of the power-electronic switches for the three-phase power converter.The feedforward control is employed to control the singlephase power converter. The neutral-line current of the utility can be obtained by summing up the detected three-phase utility currents and is then sent to an amplifier of gain . The output of the amplifier is sent to the PWM circuit to serve as the modulation signal. The PWM circuit adopts unipolar PWM to generate four PWMsignals for the power-electronic switches of the single-phase power converter.

IV.SIMULATION RESULTS

BALANCED LOAD CIRCUIT AND WAVEFORMS

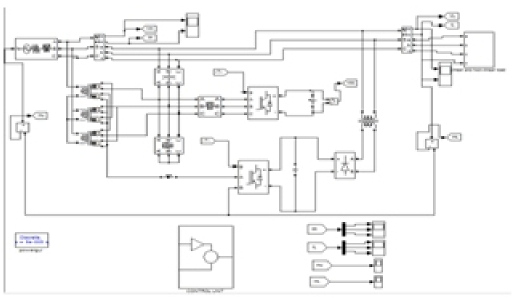

Fig.4.Balanced load circuit

LOAD CURRENT

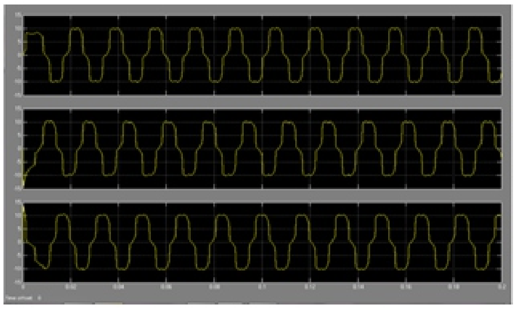

Fig.5 Waveforms of the balanced three-phase load: (a) phase a load current, (b) phase b load current, (c) phase c load current

UTILITY CURRENT

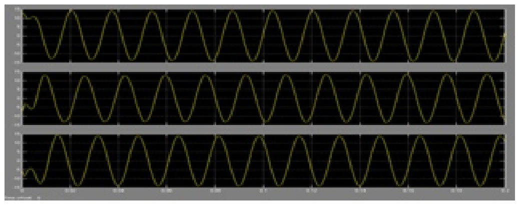

Fig. 6 Waveforms of the hybrid power conditioner under the balanced three-phase load: (a) phase a utility current, (b) phase b utility current,(c) phase c utility current

LOAD NEUTRAL CURRENT

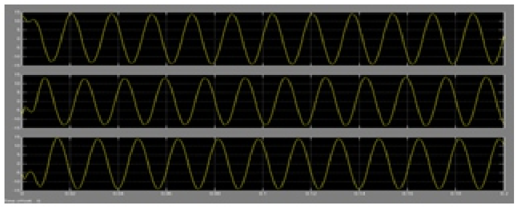

Fig 7 waveform for neutral current at load

UTILITY NEUTRAL CURRENT

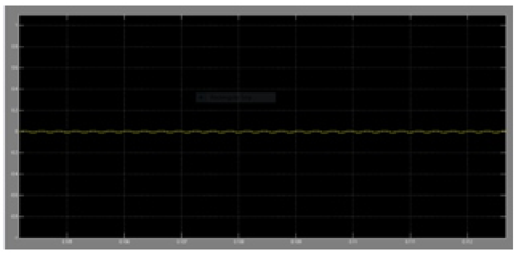

Fig.8 Wave form for neutral line current of utility.

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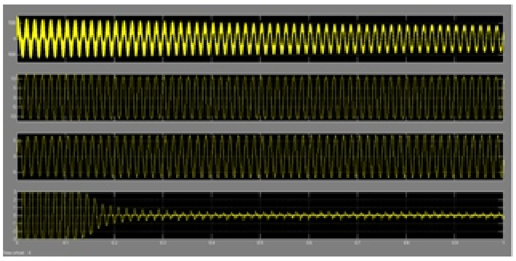

Fig.9 Waveforms of three phase four-wire hybrid power conditioner under the transient of applying the neutral-line current attenuator (a)Phase a utility voltage(b) phase a utility current (c)phase a load current (d)neutral line current line current of the utility

UNBALANCED LOAD CIRCUIT AND WAVEFORMS:

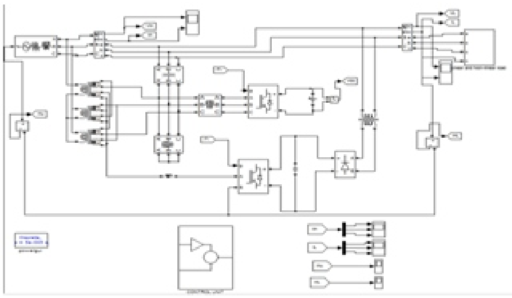

Fig 10. Unbalanced load circuit

UTILITY CURRENTS:

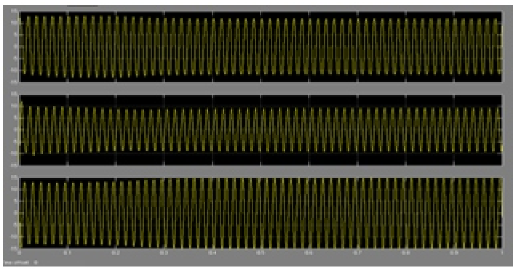

Fig. 11 Wave forms of the hybrid power conditioner under the unbalanced three-phase load: (a) phase a utility current, (b) phase b utility current,(c) phase c utility current

LOAD CURRENTS

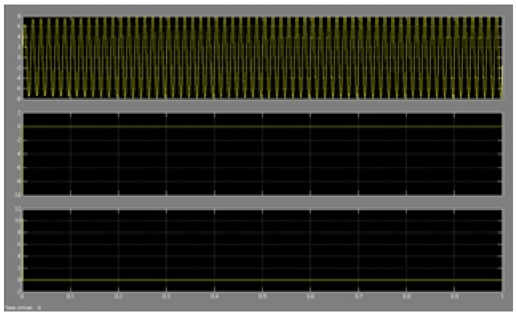

Fig. 12Waveforms of the unbalanced three-phase load, (a) phase a load current, (b) phase b load current, (c) phase c load current

LOAD NEUTRAL CURRENT

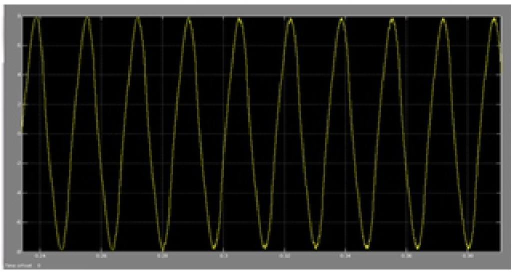

Fig. 13 Waveform of the neutral line current of the load.

UTILITY NEUTRAL CURRENT

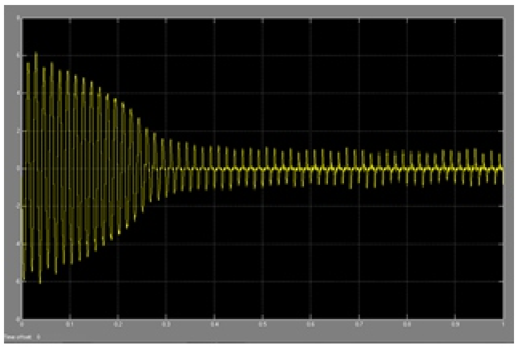

Fig. 14 Wave forms of neutral line current of the utility.

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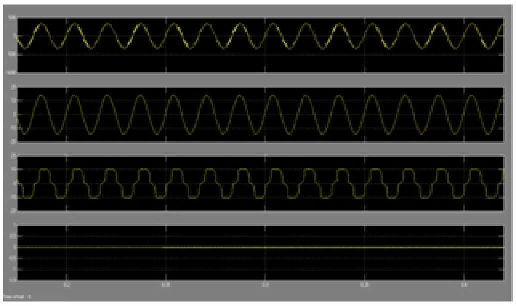

Fig.15waveforms of hybrid power conditioner under the transient of increasing load (a) phase a utility voltage (b) phase a utility current (c) phase a load current (d) neutral line current of the utility

V. CONCLUSION:

Three-phase four-wire distribution power systems have beenwidely applied to low-voltage applications; however, theyencounter serious problems of harmonic current pollution andlarge neutral-line current. In this paper, a new hybrid powerconditioner, composed of a hybrid power filter and a neutral-line current attenuator, is proposed. In the proposed hybridpower conditioner, the power capacity of power converters inthe hybrid power filter and neutral-line current attenuator can be effectively reduced, thus increasing its use in high-powerapplications and enhancing the operation efficiency.

A prototype is developed and tested. Experimental results verifythat the proposed hybrid power conditioner can suppress theharmonic current and attenuate the neutral-line current effectively whether the loads are balanced or not. Hence, theproposed hybrid power conditioner is an effective solution to the problems of harmonic currents and neutral-line current in three-phase four-wire distribution power systems. Besides,the output current of the three-phase power converter is muchsmaller than the conventional hybrid power filter, and the powerrating of the zig-zag transformer is smaller than the rating of the conventional neutral-line current attenuator.

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