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A COCKCROFT–WALTON VOLTAGE MULTIPLIER FED BY A THREE-PHASE-TO-SINGLE-PHASE MATRIX CONVERTER WITH PFC

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ABSTRACT

This project proposes a single-stage three-phase-to single-phase current-fed high step-up ac–dc matrix converter. The proposed converter inserts a boost-type matrix converter, which is formed by three boost inductors and six bidirectional switches, between a three-phase ac source and a Cockcroft–Walton voltage multiplier (CWVM).

By using this topology associated with power factor correction technique, the proposed converter not only achieves almost unity power factor and sinusoidal input currents with low distortion but also obtains high voltage gain at the output end.

Moreover, the matrix converter generates an adjustable-frequency and adjustable-amplitude current, which injects into the CWVM to regulate the dc output voltage and smooth its ripple. With this flexible injection current, the performance of the proposed converter is superior to the conventional CWVM,which is usually energized by a single-phase ac source.

The operation principle, control strategy, and design considerations of the proposed converter are detailed in this project.

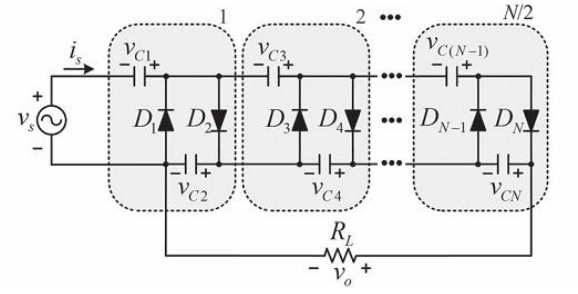
I. INTRODUCTION

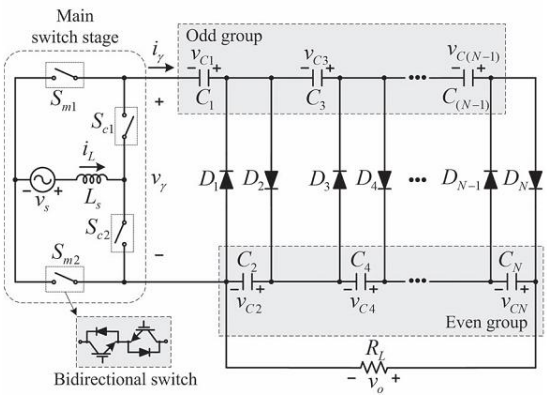
Conventionally, most of the dc sources were usually generated from ac–dc converters, except some dc-powered systems. Depending on the application requirements, many circuit topologies have been well developed for different voltage levels, different power rating, and different ac sources. When high dc voltage was required, high voltage gain was an important issue to determine the suitable topologies to achieve the high voltage output. Boost-typenonisolated dc-dc converters, which not only provide high voltage gain but also promise high efficiency and compactness, were popular for high-voltage applications. When these kinds of converters were supplied by ac source, an ac–dc stage had to deploy at the front end to form a two-stage topology.

Thus, the advantages of these high step-up converters will be deteriorated. When necessary, these two-stage topologies could employ a high-frequency step-up transformer to obtain more voltage gain. However, this led to increasing cost and bulk, and decreasing efficiency further.

When high power was required, three-phase ac sources were superior to single-phase ac sources in providing energy to the aforementioned ac–dc converters. three-phase single-stage ac–dc power converters, including buck type, boost type, buck–boost type, multilevel type, and multi pulse type, were summarized. in this review literature, most of these ac–dc converters used power factor correction (pfc) techniques to improve the ac line conditions in terms of power factor (pf) and total harmonic distortion of input currents (thd) and offered adjustable or regulated output for the variable loads.

II CIRCUIT OPERATION FOR PROPOSED CONVERTER





(b)

Fig. 1 Conventional N /2-stage CWVM. (b) CWVM fed by a single-phase-to-single-phase matrix converter

Theoretically, both boost-type and boost-buck-type ac–dc converters can provide high voltage gain with extremely high duty cycle. These topologies rarely appeared in high-voltage dc applications, such as x-ray systems, dust filtering, insulating test, and electrostatic coating, because some non-ideal characteristics of power components seriously limit the theoretical gain. Providing the advantages of high voltage gain, low-voltage stress, compactness, and cost efficiency, the well-known Cockcroft–Walton voltage multiplier (cwvm), which is constructed by cascading capacitor-and-diode pairs, as shown in fig. 1(a), is very popular among high-voltage dc applications. Traditionally, some applications combined high step-up ratio transformers with cwvm to generate high-voltage dc output [19]. However, these high step-up line-frequency transformers led to inefficiency of bulk and cost, and large amount of voltage drop and ripple appeared at the dc output. with the development of solid-state self-commutating de-vices, some ac–dc converters based on cwvm, including both single-stage and two-stage configurations with pfc, were presented to obtain high voltage gain and high quality of line conditions. a previous work of this paper was presented, in which the cwvm was fed by a single-phase-to-single-phase matrix converter, as shown in Fig1(b). This converter provided variable-frequency and variable-amplitude current to regulate the dc output voltage and smooth the ripple voltage. Moreover, the line condition was improved through pfc technology by using a commercial control integrated circuit. However, almost all these kinds of ac–dc converters were sourced by single-phase utility, and only few of them were powered by three-phase source.

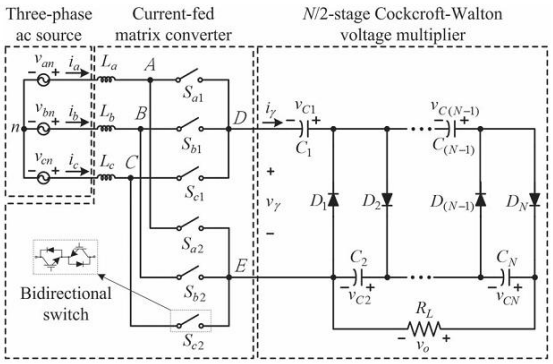
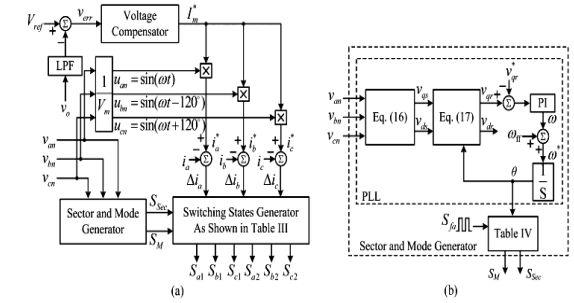


Fig. 2.Configuration of the proposed converter with an N /2-stage CWVM.

Two single-stage three-phase ac–dc converters based on asymmetrical and symmetrical cwvms were proposed, respectively. both the two converters provided high voltage gain, high PF, low thdi, and regulated dc output; it required an additional low-pass filter (LPF) to eliminate discontinuous input currents, and the voltage gain could only reach the value of conventional cwvm;the symmetrical topology used more components in each stage, and the three canter tap transformers led the topology to inefficiency of bulk and cost. Recently, some matrix converters have been proposed to transfer three-phase source to single-phase source. in this paper, a novel three-phase-to-single-phase current-fed high step-up ac–dc matrix converter is proposed to energize the cwvm. The proposed converter provides higher voltage gain than conventional cwvm without using line- or high-frequency step-up transformer. Moreover, with PFC technology, the proposed converter draws power from three-phase utility with nearly unity pf and sinusoidal input currents. Furthermore, the matrix converter generates an adjustable-frequency and adjustable-amplitude current, which injects into the cwvm to regulate the dc output voltage and smooth its ripple.

With this flexible injection current, the performance of the proposed converter is superior to the conventional cwvm, which is usually energized by a single-phase ac source. in section ii, the mathematical model of the proposed converter is derived, and the operation principle of the proposed converter will be presented as well. The control strategy will be described in section iii. in section iv, the theoretical analysis of ripple voltage at the output will be derived, and the design considerations will be given as well. In section v, both simulation and experiment of the proposed converter will be conducted.

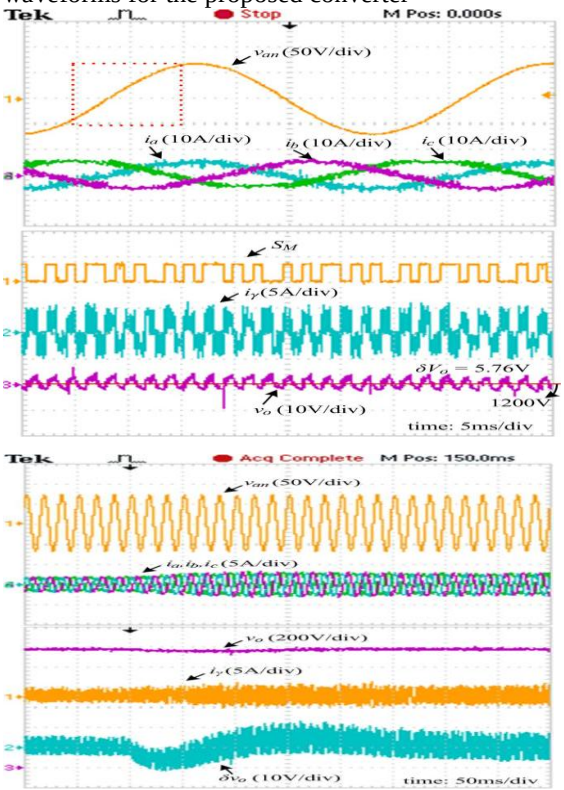
A 500-w prototype is built for evaluation and measurement. Some selected operation cases with different parameters are investigated, and the results show the good performance of the proposed converter.



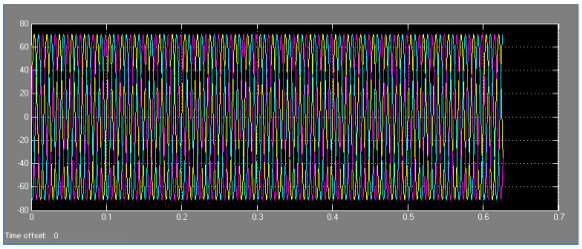
Control circuit

III SIMULATION RESULTS

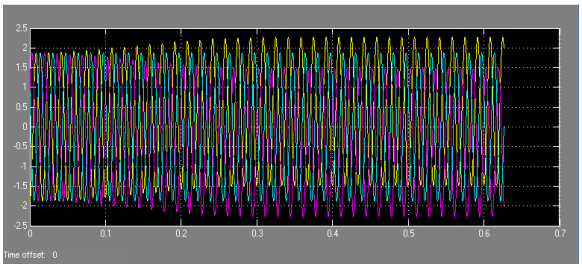
Extending from a previous work published in [35], simulations and experiments are conducted to demonstrate the performance of the proposed converter. Based on the proposed scheme, operation principle, and design considerations described in previous sections, two simulation cases with different alternation frequency were conducted by the software toolMATLAB/Simulink/SimPower to evaluate the performance of the proposed converter. Experimental waveforms for the proposed converter



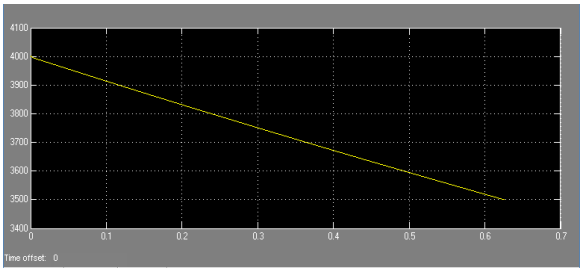
INPUT VOLTAGE AC



INPUT CURRENT



OUTPUT VOLTAGE



Experimentalresultsoftheloadvariation from 300to500Wwithfa=720Hz.

IV. CONCLUSION

In this paper, a three-phase-to-single-phase current-fed high step-up ac–dc matrix converter based onCWVMwithout a line andHigh-frequency step-up transformer has been presented to obtain high voltage gain. By using current hysteresis controlto implement PFC, the proposed converter offers almost unityPF with low THD*i*at the ac mains; meanwhile, the matrix Converter provided an adjustable-frequency and adjustable amplitude

Current to feed the CWVM to regulate the dc output and smooth ripple voltage.

V. REFERENCES

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