Pure Sinusoidal Output Current-Source Inverter Using Analog Linear Compensator

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***Abstract*—A new hybrid multilevel current-source inverter (CSI) is proposed in this paper. The proposed CSI is composed of a H-bridge, several DC current modules, and an analog linear compensator. This compensator is utilized to superimpose a linear compensating current onto the staircase current waveform generated by the DC current modules in order to reform the output current to a pure sinusoidal waveform. As a result, an output current with low harmonics can be delivered to the load without using a large output filter. The efficiency of the proposed system can be over 80% according to computer simulations.**

Keywords—multilevel current-source inverter; superimposition; staircase current; linear compensating current; harmonics; efficiency; computer simulations

I. INTRODUCTION

In general, power converters are basically operated by means of a switching action to increase their conversion efficiency. In order to reduce the harmonics caused by the switching action, large output passive filters are always needed and indispensable. On the other hand, linear amplifiers such as class-A can generate a pure sinusoidal waveform but with very poor power conversion efficiency.

The goal for inverter development is to generate the pure sinusoidal waveform with a low total harmonic distortion (THD) without any large output passive filters and without sacrificing its efficiency. Methods to achieve this goal are either using high-frequency pulse-width modulation (PWM) techniques or employing multilevel techniques. However, each technique has own disadvantages. The high frequency switching techniques lead to high switching losses, meanwhile the multilevel techniques bring high conduction losses. Therefore, it is required to develop a power converter that can solve the above all problems at the same time.

The authors [1] have reported a new concept of a hybrid CSI by incorporating several DC current modules and a linear current generator as described in Fig. 1. However, the actual implementation of the proposed idea is still unclear from the viewpoint of the power source configuration. The system can be improved if only a single power source is used.

This paper will clearly summarize the operation principle and elaborate the implementation of the proposed design of the single-phase hybrid multilevel CSI. In the end of the paper, some simulation results are presented on the basis of their measured quantities.

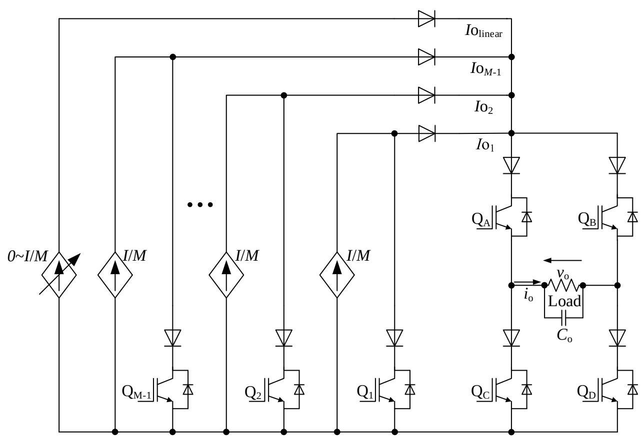

Fig. 1. Proposed concept of hybrid current-source inverter.

II. CIRCUIT CONFIGURATION

Fig. 2 illustrates the operation principle of the proposed system. In order to realize this basic operation with a single power source, the Fig. 1 is synthesized into a circuit depicted in Fig. 3. As described in Fig. 2, the staircase current waveform is generated by the several DC current modules where each module is represented by the circuit in Fig. 4. Then, a linear current generated by the circuit in Fig. 5 is superimposed onto this staircase current waveform and becomes a fully rectified DC current waveform. In order to generate sinusoidal waveform, a H-bridge is utilized to alternate the polarity of the current whenever the zero-crossing of the reference is detected.

In order to control the current amplitude, the system senses the output voltage and generates the maximum peak output current, and this value becomes the reference after divided by the number of levels. By applying this technique, the output current will be constructed in the same number of levels regardless of the load condition. In order to implement this technique, a controller circuit of the proposed system is designed as shown in Fig. 6.

The main drawback of linear current generator is low efficiency. In order to minimize the power losses, the peak current of the linear generator must be limited as low as possible. As consequence, the current from each DC current module is equally limited as well. Therefore, a high number of levels is required for supplying the load with optimum power conversion efficiency.

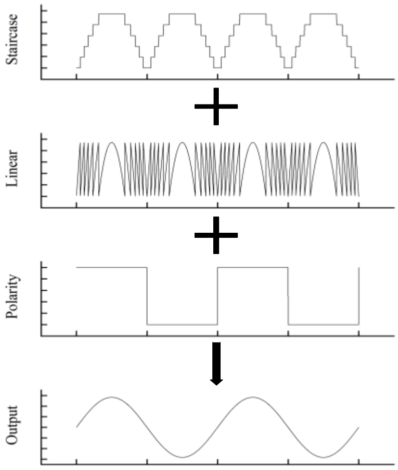

Fig. 2. Operation principle.

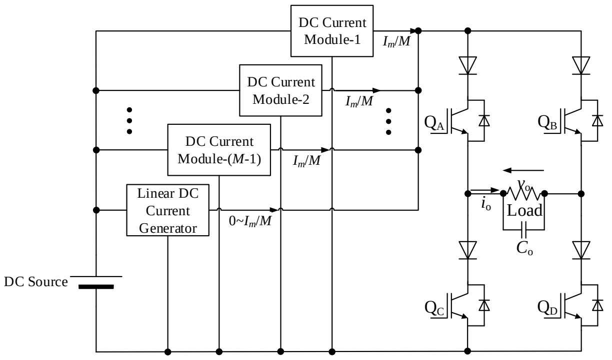

Fig. 3. Proposed system.

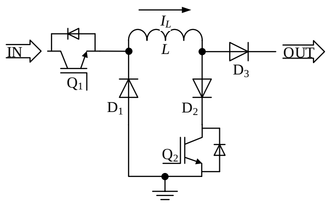

Fig. 4. DC current module circuit.

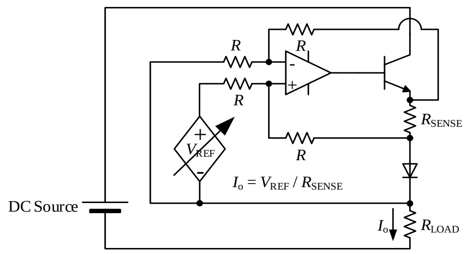

Fig. 5. Linear compensating current generator circuit.

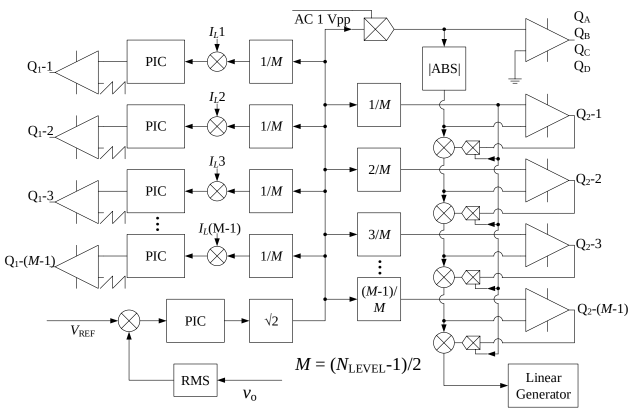

Fig. 6. Controller circuit of the proposed system.

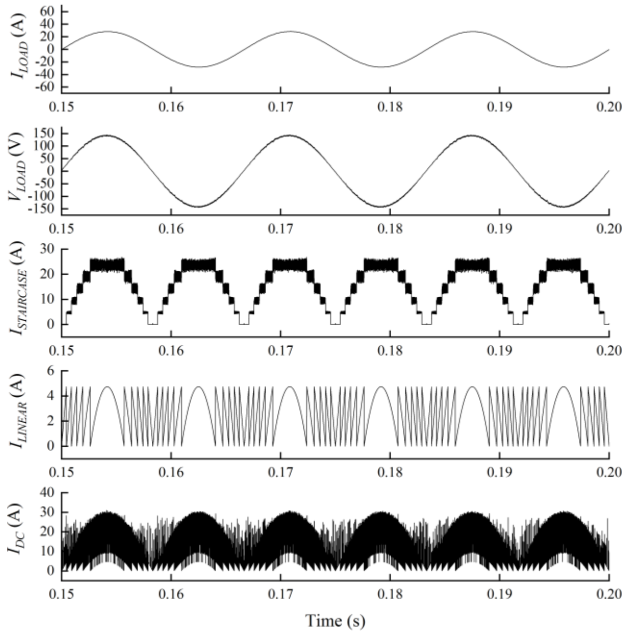

Fig. 7. 13-level hybrid multilevel CSI simulation result.

TABLE I. SIMULATION RECORDED DATA.

	Number of Levels		
	13-level	17-level	21-level
Load current	20.0 A	20.0 A	20.1 A
Load voltage	100.3 V	100.0 V	100.8 V
DC current	12.3 A	11.9 A	11.9 A
THD-I after filtering	0.35 %	0.43 %	0.49 %
THD-I before filtering	5.83 %	8.07 %	10.1 %
THD-V	1.17 %	1.57 %	2.51 %
Efficiency	81.8 %	83.7 %	85.5 %

III. SIMULATION TESTS

Computer simulations have been conducted to verify the proposed system. For comparison purpose, 13-, 17-, and 21-level hybrid CSI configurations are tested. For simulation parameters, the DC power source voltage is 200 V, inductor L is 1 mH, the output capacitor C_O is 6.8 μF, the load is 5 Ω/0.5 mH, and the output voltage is set to 100 V/60 Hz. Fig. 7 shows one of the simulation results, meanwhile the measured quantities of the conducted simulations are listed in TABLE 1. It is shown that the efficiency of the proposed system is improved according to the number of levels. However, the THD is increasing as well but still under 5 % tolerance.

IV. CONCLUSION

A new technique to generate a pure sinusoidal output current using an analog linear compensator has been presented with simulation results. By enlarging the number of levels, the efficiency of the proposed hybrid multilevel CSI can be improved. In order to verify the simulations, the proposed circuit is currently being investigated in several hardware experimental setups.

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