# Pure Sinusoidal Interconnection To The Power Grid Using H-Bridge Multilevel Current-Source Inverter And Linear Current Compensator

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***Abstract*—This paper proposes a new method of grid-connected photovoltaic (PV) system using H-bridge multilevel current-source inverters (CSI) and a linear current compensator. The proposed system consists of several H-bridge CSI which are incorporated to generate staircase multilevel current waveform and a current compensator that generates a linear compensating current. This battery-driven linear compensating current is then superimposed onto the staircase multilevel current waveform in order to reform the output current to a pure sinusoidal waveform. As a result, the power grid is fed with a pure sinusoidal current waveform and the power quality is being kept in good condition. The computer simulations confirmed the proposed system is able to deliver power with acceptable efficiency and give outstanding total harmonic distortion by only using small passive filter.**

***Keywords—Photovoltaic system; H-bridge multilevel current-source inverter; linear current compensator; superimposition; power quality; computer simulations;***

## I. INTRODUCTION

In distributed power generation applications, especially for the PV system, the DC power is fed into the grid by using a grid-connected inverter. However, the distributed generation resources have their own integration issues such as intermittent and unpredictable generation, so they create many stability issues for voltage and frequency. Therefore, the application of CSI as a grid-connected inverter for renewable energy sources gives an alternative solution to solve grid instability [1].

Since the conduction loss is the main disadvantage of the CSI, in order to achieve an acceptable power efficiency, the current inversion process must employ a fundamental frequency instead of high switching frequency modulation. The latter is only needed for the front-end process that converts PV output voltage into current with maximum power point tracking (MPPT) algorithm.

Besides considering the power efficiency, various international standards such as IEEE-1547, IEEE-929, and EN-61000-3-2, assert requirements on the output power quality of the inverters. They require the total harmonic distortion (THD) of the voltage and current have to be below the specified limits [2].

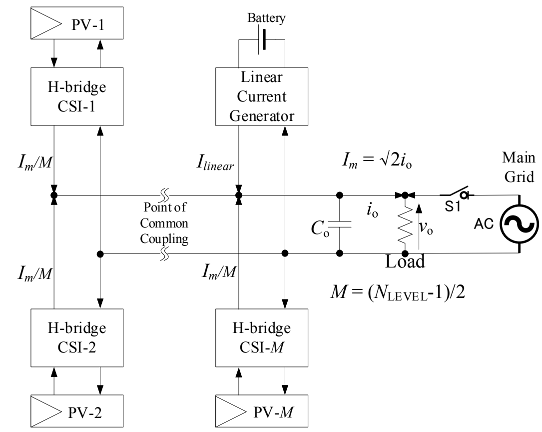


Figure 1. Proposed system.

The possible solution to solve the problems is by applying a multilevel technique into CSIs. The method for generating a multilevel current waveform is by paralleling some H-bridge CSIs. However, in order to achieve an acceptable power quality, it requires a current compensator for compensating the current into a pure sinusoidal waveform [3].

As shown in Figure 1, all H-bridge CSIs and linear current generator outputs are connected to a point of common coupling (PCC). A small capacitor $C_o$ is used for final filtering the generated currents. Prior to grid-connected process, voltage and frequency of the PV system must be set equally and in-phase to the main grid with a minimum load assistance. After being locked by the system's phase-locked loop (PLL), the switch *S1* connects the main grid to the PV system. Finally, the PV system may deliver more currents to the heavier load.

This paper summarizes the operation principle and the switching strategy of the proposed system. Several computer simulation results are presented on the basis of their measured quantities.

## II. OPERATION PRINCIPLE AND CONTROL STRATEGY

Figure 2 illustrates the operation principle of the proposed system. Each H-bridge CSI generates asymmetrical 3-level current waveform and then are summed up to result

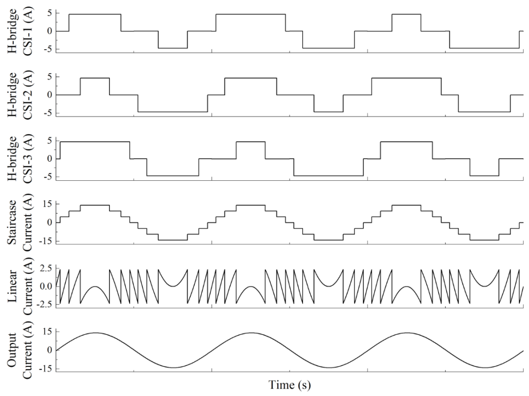


Figure 2. Operation principle.

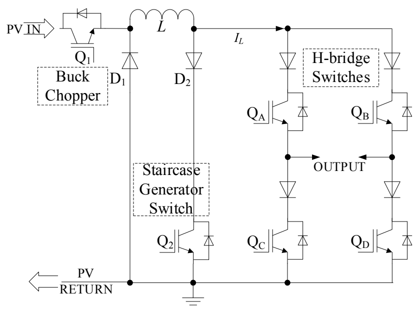


Figure 3. H-bridge current-source inverter module.

symmetrical staircase current waveform. The linear current generator superimposes the staircase waveform with a linear current and reforms the output current into a pure sinusoidal waveform. Figure 3 describes the H-bridge CSI circuit. It consists of a buck chopper (*Q1*, *D1*, *L*), a staircase generator switch (*D2*, *Q2*), and a H-bridge (*QA*-*QD*). The asymmetrical 3-level current waveform generation intends to balance the current stress in the staircase generator switch of each inverter. Therefore, each inverter consecutively exchanges the duty cycle of the level every half period of the sinusoidal reference. In order to generate a linear compensating current, a class-A linear amplifier with emitter follower configuration is used and combined with a H-bridge circuit as shown in Figure 4.

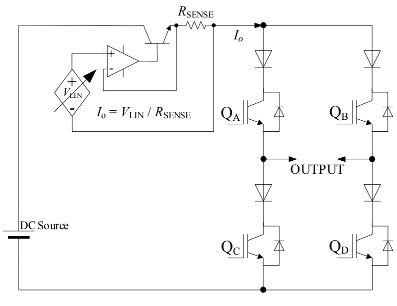


Figure 4. Class-A amplifier-based linear current generator.

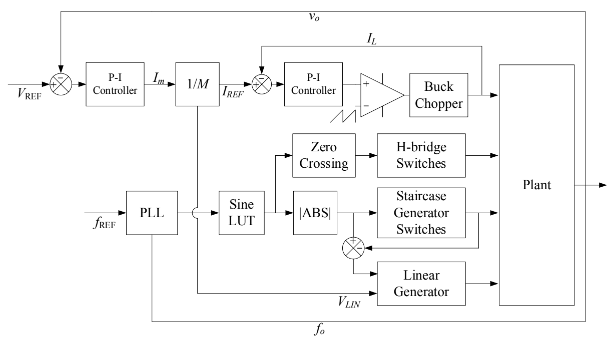


Figure 5. Control scheme of the proposed system.

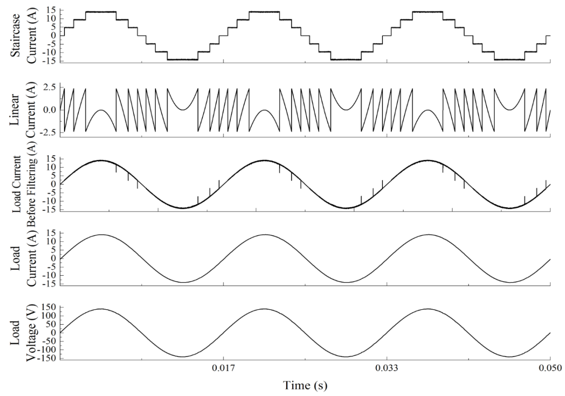


Figure 6. 7-level H-bridge hybrid multilevel CSI simulation result.

TABLE I. SIMULATION RECORDED DATA.

| | Number of Levels | | |
|---|---|---|---|
| | 7-level | 9-level | 11-level |
| Power Efficiency | 78.4 % | 81.5 % | 83.4 % |
| THD-I after filtering | 0.44 % | 0.54 % | 0.71 % |
| THD-I before filtering | 1.69 % | 1.65 % | 1.77 % |
| THD-V | 0.49 % | 0.58 % | 0.75 % |

Figure 5 shows the control scheme of the proposed system. There are three controllers utilized in the system. First controller maintains the output voltage $v_o$ as well as determines the current references $I_{REF}$ and linear reference $V_{LIN}$. The second one is used for controlling the inductor current $I_L$ of the buck chopper part. And the last one is for grid frequency $f_o$ synchronization. This control scheme is designed to control all utilized H-bridge CSIs in the PV system.

## III. SIMULATION RESULTS

Computer simulations have been conducted to verify the proposed system. For comparison purpose, 7-, 9-, and 11-level configurations were tested. For simulation parameters, each DC power source voltage is 160 V, the inductor $L$ is 1 mH, the capacitor $C_O$ is 6.8 μF, the load is 10 Ω/1 mH, and the output voltage is set to 100 V/60 Hz. Figure 6 shows the 7-level of the proposed system simulation result. It was confirmed the small output capacitor is sufficient to filter the generated current. Table 1 listed measured quantities of the conducted simulations. It is shown that the efficiency of the proposed system was improving when implemented in higher number of levels. However, the THD-V was increasing as well but still below 1%.

## IV. CONCLUSION

A new method to feed the power grid by using several H-bridge multilevel CSIs with a linear current compensator for the PV system has been presented with simulation results. In order to verify the simulations, the proposed circuit will be investigated in hardware experimental setups.

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