A Novel Soft-Switching Modular Inverter for Photovoltaic PCU with High Efficiency and Reduced Size

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1. Introduction

With the widespread concerns for sustainable development and peaceful community, the environment and available natural resources have been paid great attention to, giving a high impetus to the development and promotion of safety and renewable energy sources. Among these energy sources, the household photovoltaic (PV) power system has been regarded as the one of the most promising approaches to utilize the renewable solar energy. The system typically consists of a PV panel to convert the solar power to electric power and a power conditioning unit (PCU) to serve as an interface between the PV panel and the grid. The PCU conditions the DC electric power to meet the requirements of the AC utility grid. The kernel of a PCU is the grid-connected inverter, which inverts the DC power to AC power and feeds the power to the utility grid.

In most of the conventional household PV power generation systems at a rating between 1 kW and 10 kW, the PCU with a centralized inverter is used. This widely used centralized inverter utilizes the conventional boost-buck PWM topology for its high reliability and simplicity. Unfortunately, this topology involves the following major drawbacks: (1) Low efficiency at high switching frequencies; (2) Low reliability due to the risk of shooting throw of the upper and lower power switches; (3) High cost and large size resulted by the large decoupling components and cooling system; (4) Safety and EMI problem because of the large ground leakage current when unipolar SPWM control scheme is used in the transformer-less PV system; (5) Lack of flexibility of system capacity expansion.

Additionally, with the conventional photovoltaic PCU composed by a centralized inverter, the problem of low reliability and poor flexibility of system capacity expansion is always encountered. Because that only a single inverter with fixed power is utilized, a single failure of the inverter results in a system failure of whole PCU. And when the number of PV panels needs to be expanded in future, the whole PCU must be replaced resulting in additional investment.

In order to solve the problem of low reliability and poor flexibility, the authors propose a PCU concept composed with multiple modular inverters. The input of each modular inverter can be paralleled or connected to different input channels, while the outputs are paralleled and connected to the utility grid.

In order to make applicable use of the modular inverter concept, the size of each module must be small enough and the cost be low. To minimize the size, high switching frequency operation is necessary. To ensure high efficiency, soft-switching techniques such as zero voltage switching (ZVS) or zero current switching (ZCS) can be applied to reduce or eliminate switching losses and lower the device stresses.

In this paper, the authors propose a high efficiency modular inverter based on the DC-link inverter topology, with a novel soft-switching scheme shown in Fig. 1. The proposed inverter features high efficiency at a high switching frequency, low ground leakage current, low EMI and reduced size. The detailed operating principles and switching signals arrangement are discussed. To testify the performance, a 1 kW prototype module has been designed, built and tested. Experimental results show that the soft-switching scheme works well and the maximum overall efficiency of 97% at 100 KHz is achieved.

Fig. 1. Proposed modular inverter with soft-switching DC-link scheme
Micro Displacement Measurement System using Self-coupling Effect of Semiconductor Laser

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Keywords : Self-coupling effect, Displacement sensor, Semiconductor laser

Recently, a line width of integrated circuit has been reduced to tens of nm and a demand for compact micro displacement sensors in the manufacturing process increases. A laser interferometer is used as a conventional method of detecting a micro displacement, but has some disadvantages; a weakness for external vibration, difficulties with optical alignment and so on. Then we proposed a compact micro displacement measurement system, which is proof against an external vibration and can detect a micro displacement without an external interferometer, by making use of the self-coupling effect of the semiconductor laser (LD).

The laser light emitted from LD is irradiated to a target. A fraction of the light backscattered by the target re-enters into the laser cavity, and interferes with the laser light in the cavity, then the output signal changes. This is referred to as a self-coupling effect. When the target displaces, a peak appears in the self-coupling signal by 1/2 wavelength. By counting this peak number, the displacement can be measured with a resolution of 1/2 wavelength. To detect displacement with less than 1/2 wavelength, the sensor head is movable, and continuously vibrates with small amplitude. The sensor head is controlled so that the vibration signal has a maximum. The displacement of target is measured from that of sensor head.

The micro displacement measurement system is shown in Fig. 1. The sensor has a double cylinder structure. LD and lens are arranged in an inner cylinder. The spring is put at the front of the inner cylinder, and a piezo electric element for sensor driver is put at the back. LD with a power of 1mW and a wavelength of 850nm is used, and laser light is focused to 27.4mm ahead on the target by the lens with a focal length and a diameter of 10mm each. The output light of LD is detected with photodiode (PD) built in LD. The receiver circuit consists of I-V converter, amplifier, band pass filter (BPF) and comparator. The output signal from BPF is sent to H8/3048 microcomputer. The amplitude of vibration signal is detected. The bias voltage to the sensor driver piezo element is increased by 256steps until the amplitude has a maximum. While the target displaces, the peak number is counted from signal of comparator. After the target displaced, the bias voltage to the sensor is also increased by until the amplitude has a maximum. The displacement of target is measured from that of sensor head and the peak number. These are processed by the microcomputer.

When a piezoelectric element is used as a target, the displacement measured by this system as a function of a real target displacement measured by a capacitance meter with a resolution of 5nm is showed in Fig. 2. The error which is difference from the real target displacement is also showed in the right vertical axis. The error bar shows dispersion in 4 time measurements. The displacement is proportional to the target bias voltage up to 1.1µm with a resolution of several nm. Average absolute error is 7.09nm. Average dispersion is 4.35%. When the sensor driver bias voltage is low, a large error appears. It may be caused by inertia of polarized molecular as the force of electric field is weak.

It is confirmed that this micro displacement measurement system using self-coupling effect is a compact and excellent one which is able to measure micro displacement with a resolution of several nm.

![Fig. 1. Micro displacement measurement system](image1)

![Fig. 2. Measured target displacement](image2)
A 3-DOF Inchworm Using Levitation Caused by Vertical Vibration

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Keywords: inchworm, positioning, micro actuator, piezoelectric actuator

We propose a three degree-of-freedom (3-DOF) inchworm-type microactuator using levitation caused by vertical vibration. The vertical vibration is generated by a piezoelectric actuator. Figure 1 shows a photo of the proposed inchworm. The inchworm usually consists of thrust elements and clamp elements. Four levitation elements are connected with four thrust elements which are stacked-type piezoelectric actuators. The levitation element consists of a mass, a piezoelectric actuator and a plate. The vertical vibration of the piezoelectric actuators lifts the levitation elements. The levitation of the levitation element eliminates the friction.

The principle is summarized as follows. The vertical vibration of piezoelectric actuator causes the levitation of the levitation element. While a vertical piezoelectric actuator vibrates and levitates, horizontal piezoelectric actuators deform in the horizontal direction and they move the levitating levitation element. By controlling the order of the deformation of the horizontal piezoelectric actuators and the vibration of the vertical piezoelectric actuators, the inchworm moves in the linear and rotational directions.

We carried out preliminary experiments. The levitation height were measured first. The levitation height about 10 µm was obtained. Then incremental horizontal displacement, and rotational displacement were obtained. These displacement was generated by the deformation of horizontal piezoelectric actuators. These experimental results show the feasibility of the proposed inchworm. The mechanism proposed in this paper is effective in a positioning system.

![Fig. 1. Proposed 3-DOF inchworm.](image-url)