DC-AC GRID CONNECTED INVERTER DESIGN FOR SOLAR PHOTOVOLTAIC SYSTEM

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ABSTRACT

This paper proposes a single-phase two stage inverter for grid-connected photovoltaic systems for residential applications. This system consists of a switch mode DC-DC boost converter and a H-bridge inverter. The switching strategy of proposed inverter consists with a combination of sinusoidal pulse width modulation (SPWM) and square wave along with grid synchronization condition .The performance of the proposed inverter is simulated under grid-connected scenario using MATLAB. Furthermore, the intelligent PV module system is implemented using a simple maximum power point tracking (MPPT) method utilizing power balance is also employed in order to increase the systems efficiency.

INTRODUCTION

Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating.A photovoltaic (PV) module is a packaged, connect assembly of typically 6×10 photovoltaic solar cells. Photovoltaic modules constitute the photovoltaic array of a photovoltaic system that generates and supplies solar electricity in commercial and residential applications. Each module is rated by its DC output power under standard test conditions (STC), and typically ranges from 100 to 365 watts. The efficiency of a module determines the area of a module given the same rated output – an 8% efficient 230 watt module will have twice the area of a 16% efficient 230 watt module. There are a few commercially available solar modules that exceed 22% efficiency and reportedly also exceeding 24%.A single solar module can produce only a limited amount of power; most installations contain multiple modules. A photovoltaic system typically includes an array of photovoltaic modules, an inverter, a battery pack for storage, interconnection wiring, and optionally a solar tracking mechanism. The most common application of solar panels is solar water heating systems. The price of solar power has continued to fall so that in many countries it is cheaper than ordinary fossil fuel electricity from the grid.

Photovoltaic modules use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module can either be the top layer or the back layer. Cells must also be protected from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones are available, based on thin-film cells. The cells must be connected electrically in series, one to another. Externally, most of photovoltaic modules use MC4 Connectorstype to facilitate easy weatherproof connections to the rest of the system.

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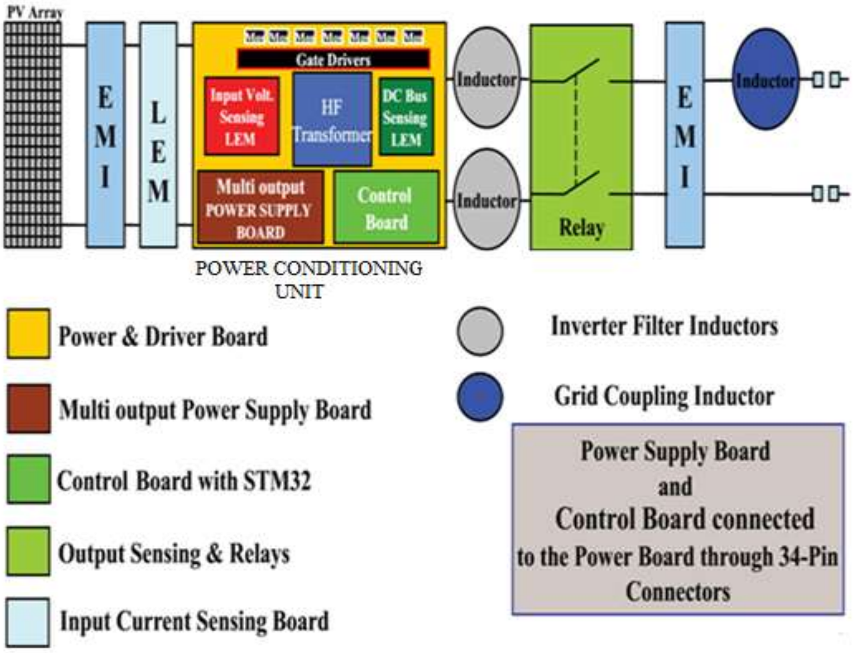
Most solar modules are currently produced from crystalline silicon solar cells made up of multi-crystalline and mono-crystalline silicon. In 2013, crystalline silicon accounted for more than 90 percent of worldwide PV production, While the rest of the overall market is made up of thin film technologies using cadmium telluride, CGIS and amorphous silicon Emerging third generation technologies use advanced thin -film cells. They produce a relatively high-efficiency conversion for the low cost compared to other technologies. Also, high-cost, high efficiency, and close-packed rectangular multi-junction (MJ) cells are preferably used in solar panels on spacecraft, as they offer the highest ratio of generated power per kilogram lifted into space. MJ-cells are compound semiconductors and made of gallium arsenide(GA-AS) and other semiconductor materials. Another emerging PV technology using MJ-cells is concentrator photovoltaic (CPV).

BLOCK DIAGRAM



Main power board , Multi-output power supply board, Control and signal conditioning board, Output sensing and relay board, Input current increasing board

The system may be completed by adding two additional boards with input and output EMI filters which, at the moment, are not included in the final prototype.

The main power board is a dual-stage converter using DC-DC to adapt voltage levels and impedance from the PV array and a sinusoidal PWM DC-AC to perform grid connection at 230 Vrms and 50 Hz. Gate driving circuitry, input and output voltage sensors of the DC-DC converter, as well as high frequency (HF) transformers, are also placed on the power board. The principle reason for using a HF transformer is the galvanic isolation provided between the PV module and the grid, to minimize the risk of hazardous operations on the PV side caused by a fault on the grid side; voltage step-up and also interruption of the resonance path formed by the parasitic capacitances to ground of the PV array and the inductance of the LCL filter. Another advantage is the elimination of high common mode currents allowing the use of unipolar pulse-width modulation for the inverter with a consequent reduction in current harmonic content compared to bipolar pulse-width modulation.

Both the multi-output power supply board and control board are connected to the main power board by means of a 34-pin connector. In this way, the connection/disconnection of the ancillary boards is very easy and allows the separation of debug and characterization.

The output sensing and relays board was realized to interface the power system and the grid. This task is accomplished with the implementation of a proper control algorithm which requires both grid-current and grid-voltage sensing. For this reason, the board is equipped with current and voltage Hall effect sensors. Two relays, controlled by an I/O of the microcontroller, are also placed on the same PCB to interrupt/connect phase and neutral of the system to phase and neutral the grid. Moreover, this board is provided with two-way connectors for electrical wiring of the LCL filter to the main power board.

The main advantage of an offline solution is the availability of a power supply for circuits dedicated to communication and data transfer even at night or in the case of weak PV field energy production. The price to pay for such an advantage is higher power consumption during standby mode of the main power unit.

The multi-output power supply board implements two independent offline flyback converters, with wide input voltage range, based on VIPER technology, to generate the following output voltages:

+5 V to supply DC-DC converter gate drivers .+5 V to supply DC-AC converter gate drivers

+5 V to supply the microcontroller +/-15 V for LEM sensors supply 24 V for relays supply

Pv System specifications

Specification	**Value**
DC-DC input voltage	200 V - 400 V
DC-DC output voltage	450 V
DC-AC output voltage	230 Vac
Nominal output power	3 kW
DC-AC switching frequency	17 kHz
DC-DC switching frequency	35 kHz
Transformer turns ratio	1.2
Grid voltage	230 Vrms +/- 20 %
Grid frequency	50 Hz
Power factor above 10 % rated power	>0.9
THD@ full load	<5 %

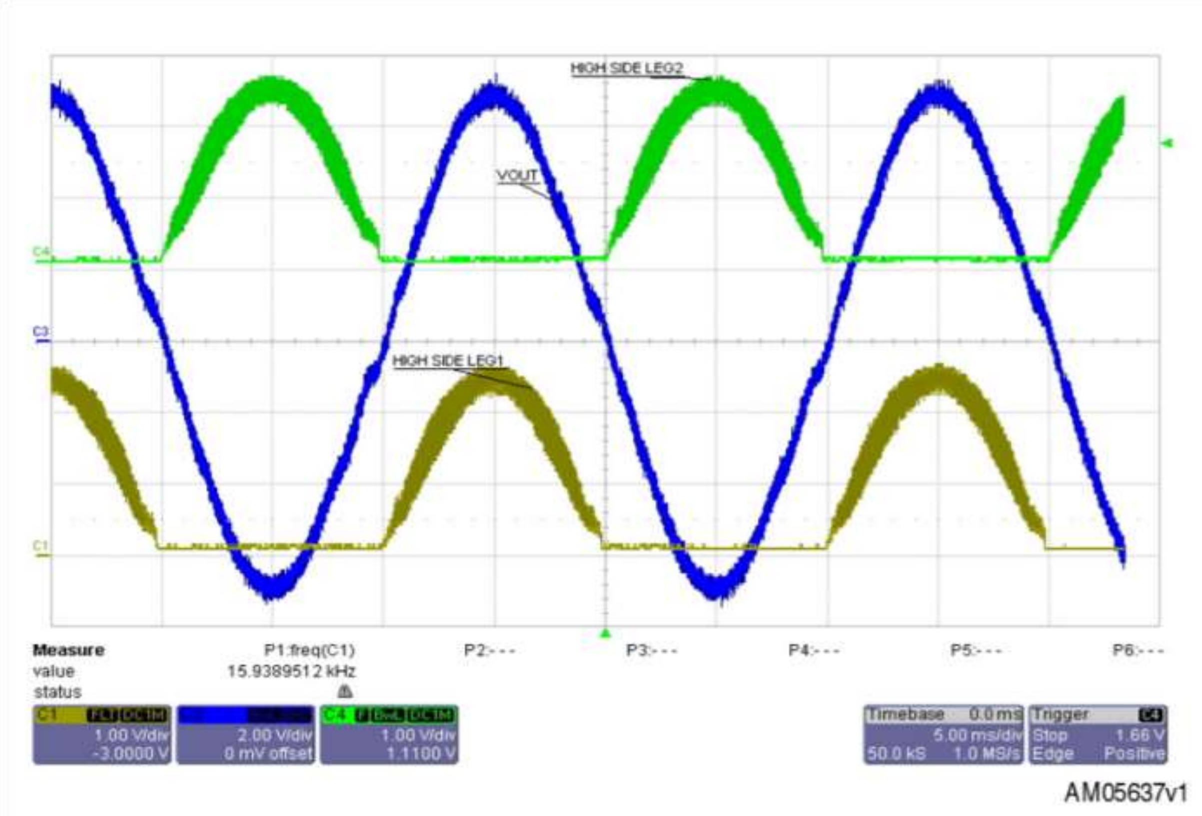
EXPERIMENTAL RESULTS

Control issues have been thoroughly investigated and the possibility of implementing the algorithm using a 32-bit ARM-based microcontroller from STMicroelectronics is verified. The dedicated control board, developed forthis purpose, is equipped with anSTM32F103xx microcontroller, characterized by a 32-bit CORTEX TM-M3 core with suitable peripherals.

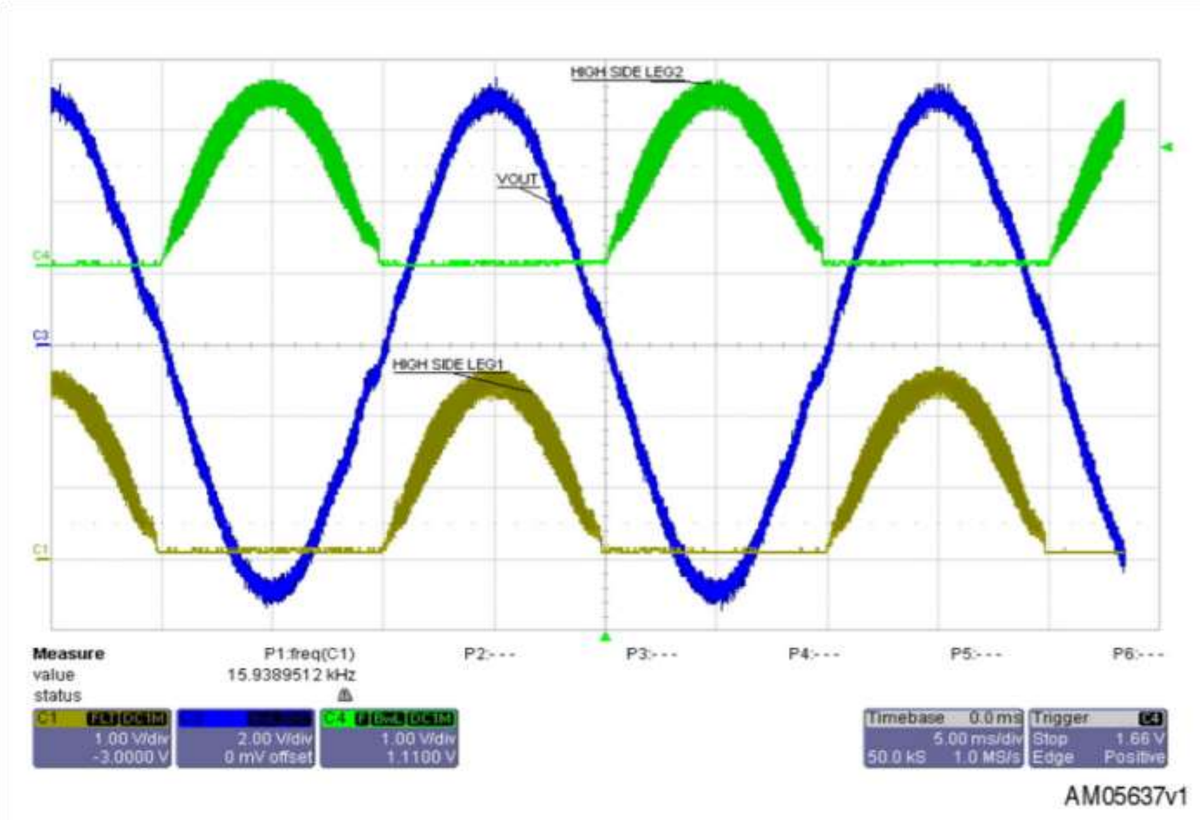
The core, running at 72 MHz, is able to perform up to 90 MIPS. A high performance CPU, based on Harvard architecture, plus suitable peripherals such as two advanced PWMs, fast and accurate 12-bit A/D conversions with double S and H circuit and high resolution timers, allows the implementation of very sophisticated control algorithms.

The entire control loop is executed in about 30 µs (50 % CPU-load) with a sampling time of 57 µs. Further code may be executed in the remaining 50 %, allowing the implementation of a HMI (human machine interface) such as LCD driving or a graphical user interface via SPI, in order to have a complete smart-platform.

The control loop has been synchronized with the A-D conversions triggered by the ON states of the two PWM timers. This brings benefits in terms of accuracy, avoiding the acquisition of analog quantities (e.g. currents) during commutations of the power devices.



Low-side device modulation (red and blue track)



High-side device modulation (yellow and green track**)**

CONCLUSION

This application note describes the design and performance of a power conversion architecture characterized by high efficiency, good integration levels and galvanic isolation, with the aim of demonstrating STMicroelectronics’ complete and high performing product portfolio to implement any PV conversion system. For this reason, the power converter, based on a dual-stage topology, has been investigated and experimentally evaluated for photovoltaic applications. The converter performs MPPT and grid connection by means of an ARM Cortex M3-based STM32F103xx microcontroller, which is proven to be well suited for such an application. In fact, the implemented DQ axis control scheme shows excellent regulation of both active and reactive power, as is also required for low power applications in the near future. Simulation and experimental results have confirmed the consistency of the proposed solution for PV generation systems.

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