LOW-POWER ON-GRID MODULE INTEGRATED INVERTER FOR PHOTOVOLTAIC APPLICATIONS

GOREMICHIN Vladimir
Institute of Applied Physics of the Academy of Sciences of Moldova

Abstract – D*ifferent system configurations of DC/AC inverters for connection of PV arrays to a grid are considered. Special attention is paid to module integrated inverter concept (so called AC modules) with the determination of their advantages. Taking into account the promising perspectives of AC modules, the low-power solar single-phase module integrated inverter has been designed. The module integrated inverter is intended, first of all, for applications with PV modules having the following parameters: Maximum Power - 240W, Open Circuit Voltage ~36.0V, Short Circuit Current ~ 8.60A, Maximum System Voltage - 600V. The developed inverter is a single-stage power flyback conversion system with the PWM Current Source Inverter topology. The Project is in the stage of the completed circuitry and PCB design. Solar AC modules are becoming a promising trend in the PV system technology, particularly, in building integrated applications in urban areas.*
Keywords: *PV on-grid inverters, AC modules*

INVERTOR DE PUTERE JOASĂ DE REŢEA INTEGRAT ÎN MODUL PENTRU APLICAŢII FOTOVOLTAICE

GOREMÎCHIN Vladimir
Institutul de Fizică Aplicată al Academiei de Ştiinţe a Moldovei

Rezumat – *Diferite configuratii de sistem ale DC / AC invertoare pentru conectarea PV matrice la o reţea sunt luate în considerare. O atenţie deosebită este acordată modul concept integrat invertor (aşa-numite module AC), cu determinarea avantajelor lor. Luând în considerare perspectivele promiţătoare de module AC, consum redus de putere solara a fost proiectat un invertor monofazat integrat în modul. Acest invertor integrat este destinat, în primul rând, pentru aplicatii cu modulele fotovoltaice cu următorii parametri: putere maxima - 240W, tensiunea circuitului deschis ~ 36.0V, curent de scurtcircuit ~ 8.60A, tensiune maximă a sistemului - 600V. Invertor elaborat este un sistem de conversie flyback de o singură etapă cu* PWM Current Source Inverter *topologia. Proiectul dat se află în stadiul de circuitele şi design PCB completat. Module solare AC devin o tendinţă de perspectivâ în tehnologia sistemelor PV, în special, în aplicaţii integrate în zonele urbane.*
Cuvinte cheie – *PV invertoare de reţea, AC module*

МАЛОМОЩНЫЙ СЕТЕВОЙ МОДУЛЬНО ИНТЕГРИРОВАННЫЙ ИНВЕРТОР ДЛЯ ФОТОВОЛЬТАИКИ

ГОРЕМЫКИН В.В.
Институт Прикладной Физики Академии Наук Молдовы

Реферат – *Рассмотрены различные конфигурации DC/AC инверторов для подключения солнечных панелей к сети. Особое внимание уделено модульно-интегрированным инверторам (АС модулям) с определением их преимуществ. Принимая во внимание многообещающие перспективы АС модулей, был разработан солнечный маломощный однофазный модульно-интегрированный инвертор. Модульно-интегрированный инвертор предназначен для применения в первую очередь с PV модулями, имеющими следующие параметры: максимальная мощность -240Вт, напряжение холостого хода ~ 36В, ток короткого замыкания ~ 8.60А, максимальное напряжение – 600В. Разработанный инвертор представляет собой однофазный flyback конвертор с ШИМ Current Source Inverter топологией. Проект находится на стадии разработанной схемотехники и PCB дизайна. Солнечные АС модули становятся многообещающим трендом в фотовольтаических системах, особенно в интегрированных в строительные конструкции в городах.*
Ключевые слова*:* *солнечные сетевые инверторы, АС модули*

Nowadays, on the photovoltaic (PV) applications market about 85% of PV Systems (PVSs) are applied in grid-tied and micro-grid systems [1]. A PV array can be connected to a grid via three different system configurations of DC/AC inverters, namely, the central inverter, the multi-string inverter and the module integrated inverter (converter) [2]. In large PV system (>10 kW) a large number of PV modules is connected to strings, while these strings are connected in parallel via string diodes or string fuses. A PV generator structured like this is then connected to the DC input of one of the central inverter [3].

Central inverters are characterized by high efficiency and lowest specific costs. However, the energy yield of the PV plant decreases because of the module mismatching and partial shading conditions [4]. Moreover, the reliability is limited as the whole system is dependent on a single power conditioner. In (multi-) string inverters, the same as with central inverters, the PV array is divided into strings. Each of these strings is assigned to its own inverter, called a string inverter. Each string operates at its individual maximum power point (MPP) and hence partly minimizes mismatching, reduces losses resulting from shading and avoids losses due to the string diodes and large scale DC-cabling compared to a central inverter. Maximum Power Point Tracking (MPPT) is a technique that grid tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more solar panels [5]. Solar cells have a complex relationships of solar radiation, temperature and total resistance, which produces a non-linear output efficiency known as the I-V curve. It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. Essentially, this defines the current that the inverter should draw from the PV in order to get the MPP, as power equals voltage times current.

Therefore, the series connection of PV modules could lead to certain MPP mismatch losses due to manufacturing tolerances and non-optimal conditions such as partial shading, or alignment in different angles. For this reason, several contributions proposed the application of DC–DC converters attached to each PV module as individual MPPT units [4]. A further step is associated with the integration of the whole DC–AC inverter unit into each PV module. The module integrated converter (MIC) concept performs power processing without accessibility to DC connections. Thus, the whole unit can be regarded as a PV “AC module” connected in parallel to the public grid [6]. Fig. 1 shows connection of AC modules to the grid [7].

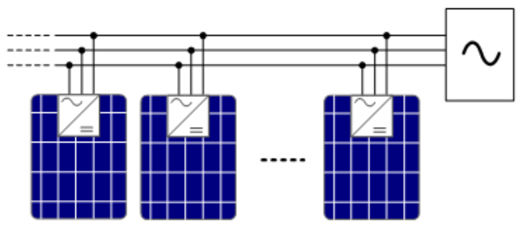

Fig.1. Connection of AC modules to the grid

So, the module integrated inverter (converter) concept, also called an AC-module, has an individual inverter with the MPPT system for each module as well as a number of advantages over the state-of-the-art system, such as:

- Minimal mismatch losses due to parallel connection of PV modules
- Single panel MPPT process with optimal energy harness from each panel (up to 20-25% increased energy harvest)
- Small losses at partial shading
- No DC-specific equipment (e.g., DC cabling, connectors, fuses) and, accordingly, reduced installation cost
- Simple system configuration, easy installation through flexible and modular PV system design
- Redundant operation – no single point failure.

Module-integrated inverters lead to higher yields especially with solar modules that are partially shaded or aligned with different angles.

Taking into account the abovementioned advantages of AC modules the low power solar single-phase module integrated inverter has been designed.

The chosen topology, a PWM Current Source Inverter, features a single-stage power flyback conversion system that feeds directly into the grid. It allows to make a system simple, highly efficient and cost-reduced. The PV panel output is converted to the sinusoidal output current and voltage in phase with the grid.

The block diagram of the proposed Module Integrated Inverter is shown in Fig.2. PV systems using module integrated inverters have peak power ratings of usually less than 500 W and consist of one to a few PV modules. Consequently, DC voltage levels are low and to reach grid voltage levels the module integrated inverter topologies require a voltage boosting element within the energy conversion chain from DC to AC.

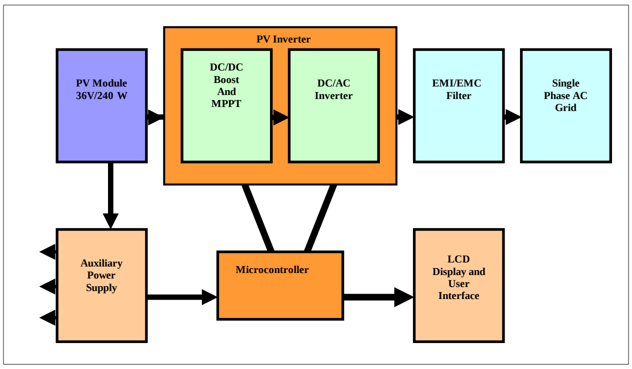

Fig.2. Module Integrated Inverter block diagram

The device dsPIC33F ‘GS’ (a Microchip Technology Inc. series product) controls power flow from the PV panel to the grid. This Digital Signal Controller (DSC) also carries out the MPPT algorithm, fault control, as well as certain optional digital communication routines. To eliminate the noises an EMI/EMC filter is used, that also ensures impedance between the inverter output and the grid. The PV panel voltage is the source of the auxiliary power for the controller and the feed-back circuitry.

The interleaved flyback topology is applied with the view of decreasing the ripple current through the input electrolytic capacitors, the large magnetic core, the output current total harmonic distortion (THD). The proposed inverter contains two flyback converters, coupled in parallel, that are 180º out of phase with respect to each other. The interleaved flyback converter general block diagram is shown in Fig.3.

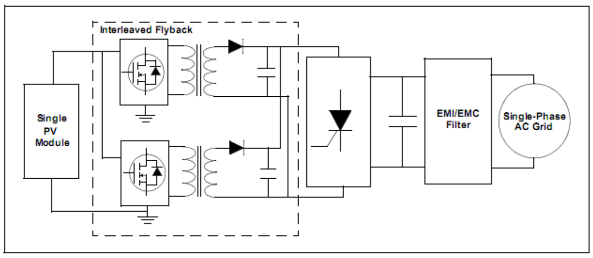

Fig.3. Interleaved flyback converter general block diagram

The module integrated inverter is intended, first of all, for application with PV modules having the following parameters:

- Maximum Power (Pmax) 240W
- Maximum Power Voltage (Vmpp) 30.0V
- Maximum Power Current (Impp) 8.00A
- Open Circuit Voltage (Voc) 36.9V
- Short Circuit Current (Isc) 8.60A
- Max System Voltage 600V
- Peak efficiency (simulated) 95%.

Now project is in the stage of the completed circuitry and PCB design. Fig. 4 shows a four-layer PCB design of the Module Integrated Inverter.

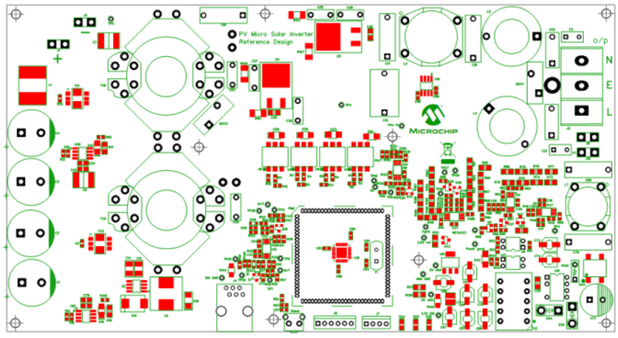

Fig.4. Four-layer PCB design of Module Integrated Inverter

Circuitry of the flyback current sense is presented in Fig.5.

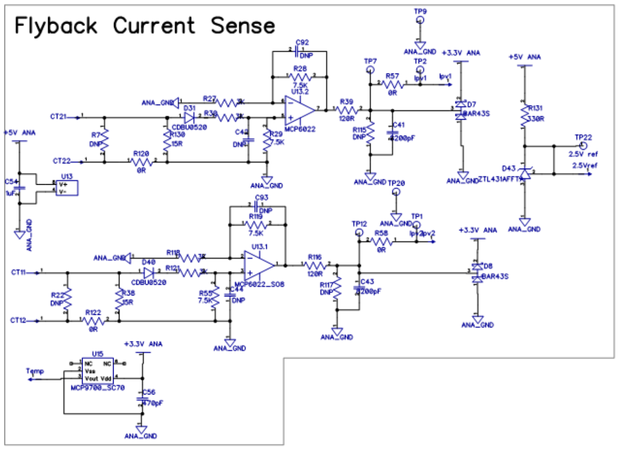

Fig.5. Circuitry of flyback current sense

To sum up, solar AC modules are becoming a promising trend in the PV system technology, particularly, in building integrated applications in urban areas. This is why the development of circuitry solutions directed at increasing the efficiency and life time of module integrated inverters is a really urgent and topical problem.

LITERATURE

[1] N. Kutkut, www.floridaenergy.ufl.edu/.../pv-energy-co..., 2009

[2] N. Henze, B.Sahan, R. Burger, W. Belschner, *EU PVSEC Proceedings*, 23rd European PV Solar Energy Conference and Exhibition, Valencia, Spain, September 2008

[3] B. Koirala, B. Sahan, N. Henze, *EU PVSEC Proceedings*. 24th European Photovoltaic Solar Energy Conference and Exhibition, Hamburg/Germany, 2009, pp. 3727 – 3733.

[4] Xiao W, Ozog N, Dunford WG, *IEEE Transcations on Industrial Electronics*, Vol.54, No.3 PP 1696-1704, June 2007

[5] www.blueskyenergyinc.com

[6] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, *IEEE Trans. Ind. Appl*., vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2006.

[7] Jiu Liu, Norbert Henze, http://www.pvmips.org/publications/017.pdf

Author:

M.Sc.Vladimir Goremichin
Institute of Applied Physics of the Academy of Sciences of Moldova, Chisinau, Chief Engineer, Head of Section of Patenting and Technology Transfer.

Area of expertise: Integrated Circuit (IC) design, Electronics for power saving technologies, Solar cells, Electronics for power engineering, Computer networks.