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Multifunctional Solar Park with "+five in one"

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Abstract: *This work describes photovoltaic solar park for family houses and residential objects with multifunction "+five in one" in range 10-100kWp. Key element of this system is Photovoltaic Converter unit which is realized as non-isolated photovoltaic string inverter with energy storage and uninterruptable power supply function. The control electronic of the inverter is described more detail in the paper. At this point, hardware of Electronic Control Module and base software were realized. The next steps of development are an energetic part of the inverters in IGBT and SiC technology, embedded software and web server.*

Keywords: *solar park; photovoltaic converter;*

1. INTRODUCTION

The situation on the solar energy market has changed sharply in the direction of a significant reduction in prices and initiative for electricity generated from solar sources. New regulations have been introduced where solar energy is increasingly gaining market and competitive forms. You could see attached graph from Fraunhofer institute (New PV roof electricity price << Domestic electricity price) Germany Feed-in tariff for small roof systems put into operation by April 2018 can be up to 12.20 €-cts/kWh and is guaranteed to the operator over the next twenty years. Serbian Feed-in tariff (Službeni glasnik RS br. 8/2013) is 20.66 €-cts/kWh.

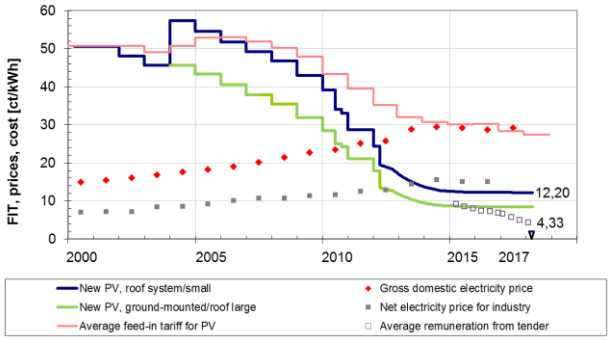


Figure 1. *Picture 3.Feed-in tariff for PV power in Germany (source Fraunhofer institute Freiburg, February 21, 2018)*

It should also be noted that the Energy Community calls on Serbia to adopt amendments to the law and support measures for renewable energy sources and the procedure of public bidding. There should be referent price, and that is a market price defined "day in advance" on hour period, on the organized electricity market [2, from 06/13/2017]). The facts about the actual and expected changes in the solar energy market led us to think about the addition and change of the solar energy paradigm in the case of a photovoltaic power plant, i.e. a garden for family houses and residential buildings. We think that future PV power plants for roof systems should be multifunctional and informatically connected to "smart grid" system. In that direction we propose the introduction of a dynamic tariff system, which implies a continuous change in the unit price of energy by the operator, that is, the public buyer and the seller of electricity (most often that is country). The expression "+ five in one" is a symbolic sign that the proposed PV system compared to the classic has additional 5-five new functions. Classic PV system works parallel with the network and any excess of electricity produced is immediately handed over the network and, that way, they become balance irresponsible producers and consumers. New system introduces high level of balance responsibility and it has been supplemented with some other attractive functions such as PV-roof, Energy Storage, UPS and REACTIVE energy production.

2. PHOTOVOLTAIC ROOF PANELS

Tesla and SolarCity developed a solar roof system that integrates the solar cells and modules inside the structure of the roof rather than just panels on a roof. They are using a high-efficiency solar cell manufactured by Panasonic and covered with a "color louver film", which allows cells to blend into the roof while exposing them to the sun above, and finally a tempered glass on top for durability. It comes with a lifetime of the house warranty and 30-year power generation guaranteed. After the electricity production, Tesla estimates that its solar roof will be cheaper than regular tile roofs or

virtually pay for itself through electricity savings. The new product was unveiled on October 28, 2016, at a joint event with Tesla and Solar City in Los Angeles. In May 2017, Tesla started taking orders with a $1,000 deposit for the first versions of its solar roof tiles and the product was sold out "well into 2018" within the first few weeks.

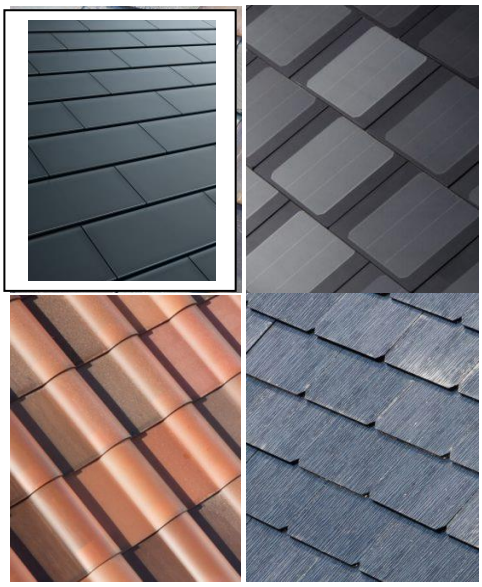


Figure 2. *Solar roof panel designs*

3. PHOTOVOLTAIC CONVERTER UNIT - STRING INVERTER "THREE IN ONE "UNIT

Designed by ElektroDRIVE d.o.o. [3] non-isolated photovoltaic string inverter with energy storage and uninterruptable power supply function.

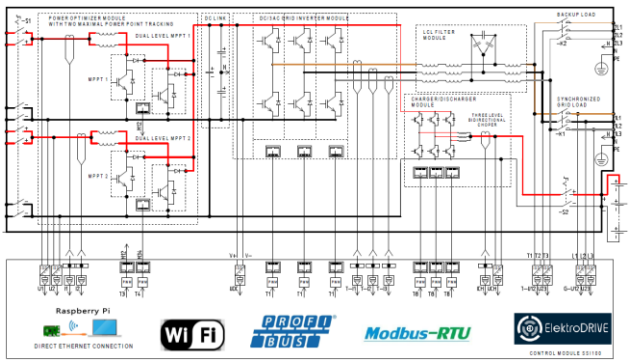


Figure 3. *Electronic Control Module (ECM) Designed by ElektroDRIVE*

- power module components
  - two power optimizer moduleswith dual level boost choper realized in igbt or sic technology;
  - dc link module;
  - dc/3ac grid inverter modulerealized in igbt or sic technology;
  - lcl filter module;
  - charger/dicharger module realized in IGBT or SiC technology;
- interface components and mechanical components
  - S1 input switch with optional with breaker;
  - S2 switch for connection with external battery, optional with circuit breakers;
  - K1 Contactor for grid connection, optional with circuit breakers;
  - K2 Contactor for connection with BACKUP load, optional with circuit breakers;
  - X Connection terminal and connectors.

Control module hardware realized with two electronic cards:

- Power supply and measuring electronic card
- CPU, gate-driver and input-output module, electronic card
  - 8 voltage measuring +/-1000Vpp convert in DSP volt gain range 0 ... 3.3 VDC
  - 6 current measuring
  - 2x3 PWM driver T1 – Three phase 6PWM driver for grid inverter
  - 2x3 PWM driver T8 – PWM driver for charger / discharger chopper
  - 2 PWM driver T3 and T4 for two level boost choppers - power optimizer MPPT1
  - 4DI, 2RO 4 digital input (galvanic isolation),2 relay outputs
  - 2AI, 1AO2 analog input and one analog output
  - Safe power off circuit for hardware shutdown – block off all PWM drivers
  - RS485 or PROFIBUS serial communication channel
  - WIFI based web server optional module node MCU ESP12E
  - Raspberry PI3 mini PC based extension optional module

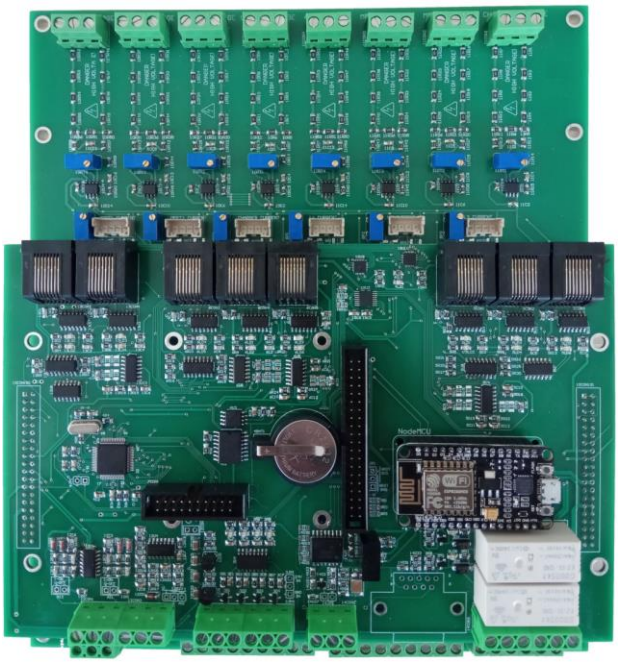


Figure 4. *Electronic Control Module (ECM) Designed by ElektroDRIVE [3]*

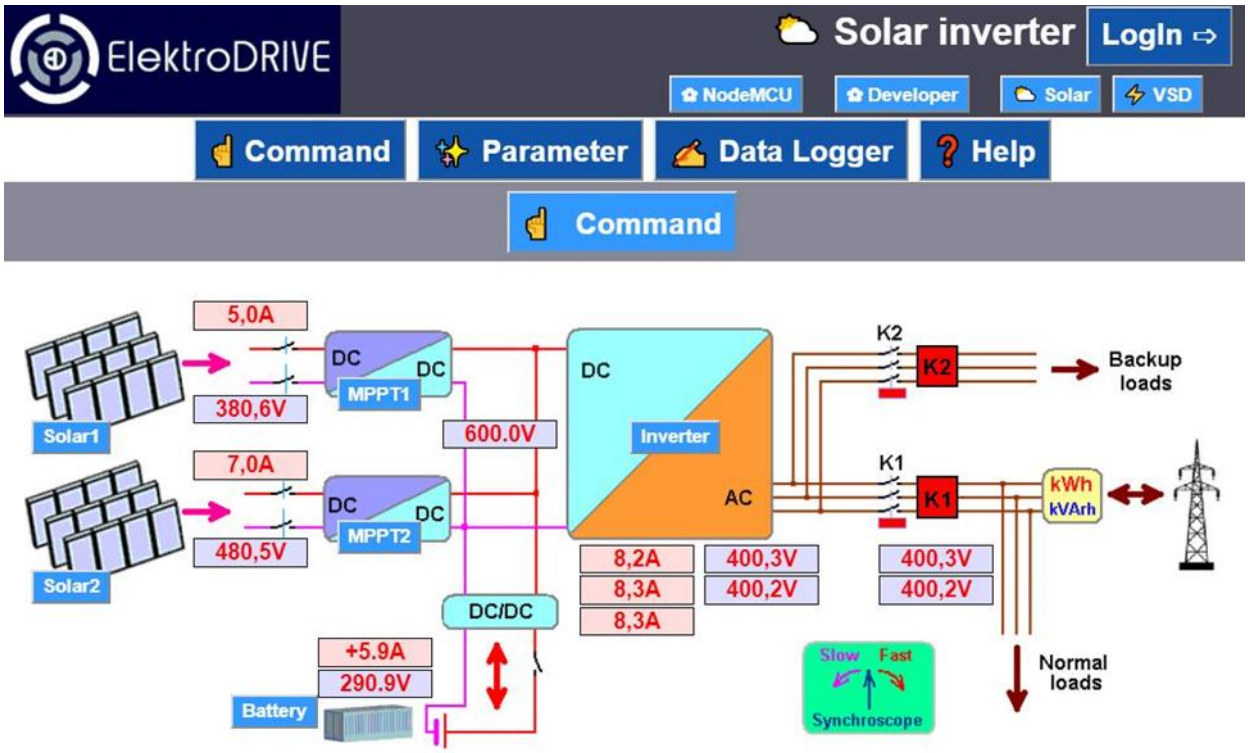


Figure 5. *HMI function with WEB server of solar inverter in development phase*

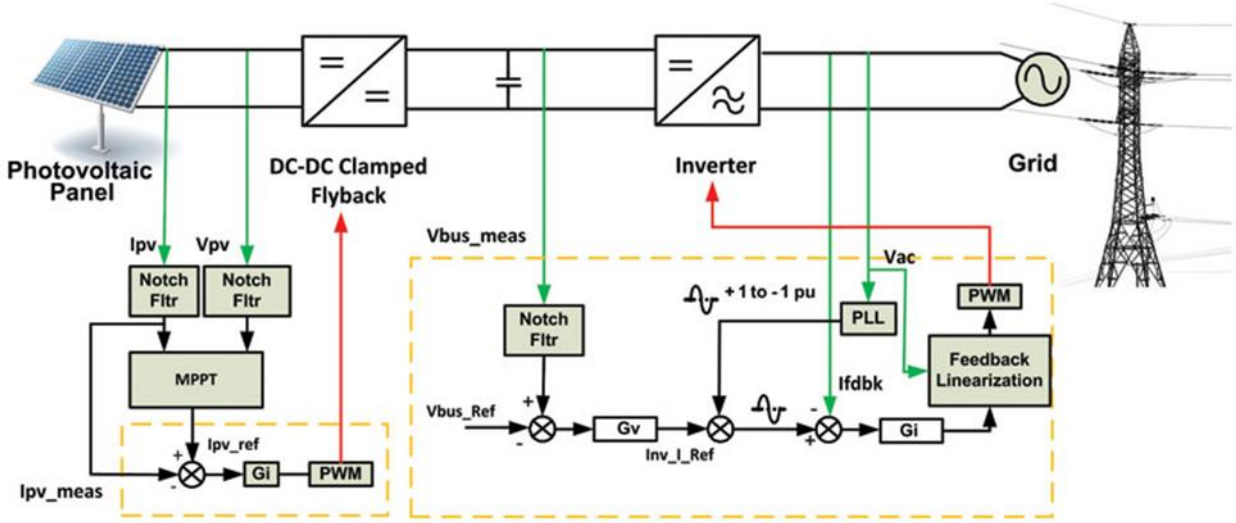


Figure 6. *Illustration of one-part embedded software-firmware which refers to MPPT and PLL*

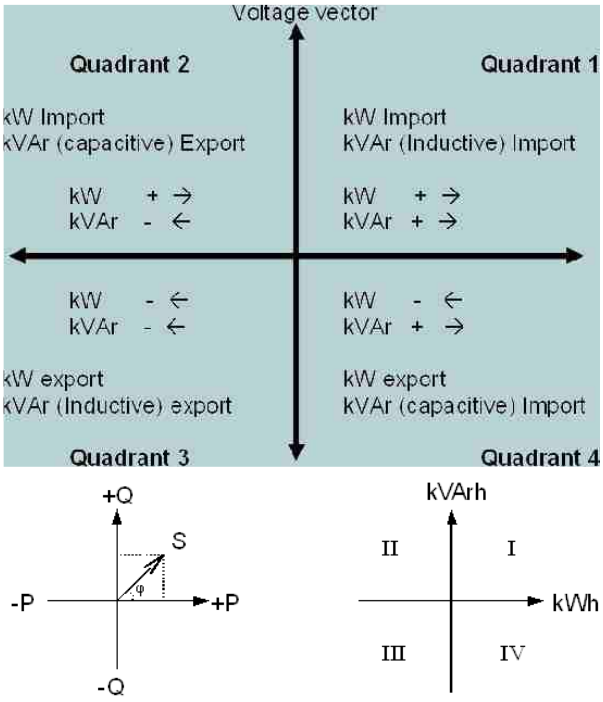
Control module firmware:

- PPT Maximal Power Point Tracking control task;
- AFE Active Front End and PLL Phase Locked Loop task;
- Synchronoscope, inverter - master grid synchronization;
- Charge/dicharge control task;
- UPS uninterruptible Power Supply interface algorithm;
- Real time comunication firmware and web server program.

4. FOUR-QUADRANT ENERGY MEASURING AND PRICE COMPUTING UNIT

Advanced bidirectional utility measure process of measuring reactive and real energy accounting both forward and reverse flows.

Four-quadrant energy measurement is supported for net metering systems with bidirectional energy flow. Voltage Sag and Swell Events Logged with Programmable Threshold Levels. Power quality monitoring and analysis in a three-phase energy



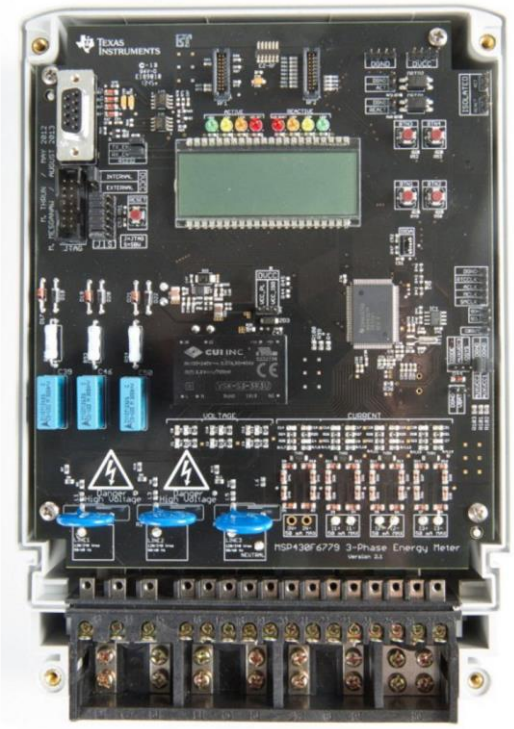


Figure 7. *Illustration of Four-quadrant energy measurement*

measurement. THD Calculated for Voltage and Current. Complete Energy Library with Fundamental Voltage and Current, Fundamental Active and Reactive Power, Active and Reactive Energy, Root Mean Square (RMS) Current and Voltage, Power Factor, Line Frequency and Dynamic Prices:

Dynamic Price for Active energyImport	DPAeIm	[€-cts/kWh]
Dynamic Price for Reactive energyImport	DPReIm	[€-cts/kVArh]
Dynamic Price for Active energyExport	DPAeEx	[€-cts/kWh]
Dynamic Price for Reactive energyExport	DPReEx	[€-cts/kVArh]

The calculation is done in such a way that integrals of import and export of Active and Reactive power is multiplied by dynamic prices. Bill in euro cents is calculated by subtraction of export sum from import. Dynamic prices of the public buyer-state change, for example, every five minutes or every hour based on the classic techno economic parameters (of course, within the framework of the contract defined rules) and immediately communicates via the Internet to buyers-sellers with whom it has a contract. Buyers and sellers, or their IT systems monitor the price (in our case it is a task of Advanced Photovoltaic Converter unit) and it decides how to work to get the maximum profit out of their power plant.

5. GRID BALANCING

In order for electrical grid to function reliably, it needs to be balanced. In practice, the Transmission System Operator achieves this by perfectly matching the consumption of electricity with the production. In traditional, fossil-fueled energy systems, production of base-load assets is scheduled to match the expected energy demand. Short-term deviations in the expected demand are then accounted for by more flexible assets that can be quickly ramped up and down, with gas fired power plants as the most popular example.

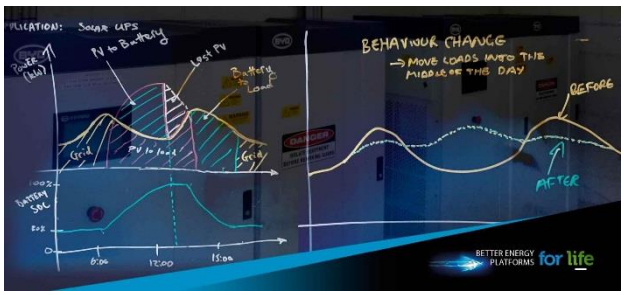


Figure 8. *Illustration of energy grid balancing*

Grid balancing has become an important aspect for the power grid in matching the supply of energy to demand. In more recent years this has become less predictable with more renewable energy being installed into the grid.

This has resulted in wind farms being turned off at night time, when it is windy, but there is no demand. In Scotland this has resulted in payouts, most recently over £6m in 33 days has been paid by the grid to wind farms to not generateelectricity.

Possible solution for this problem are batteries. To provide flexibility, the battery should (on average) be loaded at 50%, giving it equal potential for on or off loading depending on the needs of the grid operator at that very moment. The capacity of the battery can be used optimally by setting its load factor based on forecasted renewable output and electricity demand.

6. CONCLUSION

Five key features of proposed photovoltaic system "+five in one"

- Usage of the roof solar panels as a roof for family houses and residential objects;
- Energy storage;
- Extra reactive energy production (Maximum kW and maximum kVA tracking);
- Taking over balancing responsibilities from the power distribution (Dynamic Price Market);
- UPS function, uninterrupted power supply for backup load;

Future paradigm of management and subvention of small roof PV power systems (PV power plants on objects, roofs):

- Public buyer - state dynamically manages prices (each hour changes the import and export prices of active and reactive energy). This way, if the seller or solar park real-time monitors the price trends, it automatically begins to behave not only as a selfish producer but also as responsible BALANSER of energy.
- It is definitely necessary to accept the fact that the current price of energy sold to the public buyer - state is always cheaper than purchasing because that normal economy requires.
- For green solar energy, state should favor in that way that small roof PV power system gets free of charge two key devices with standardized software:
  - Four-quadrant energy metering and price computing unit;
  - Advanced Photovoltaic Converter unit"+five in one".

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