DOI: https://doi.org/10.15407/techned2020.04.055

MANAGEMENT OF GENERATION AND REDISTRIBUTION ELECTRIC POWER IN GRID-TIED PHOTOVOLTAIC SYSTEM OF LOCAL OBJECT

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Photovoltaic grid-connected system of local object with a battery when using a grid inverter with an "open" input is presented. The expediency of the structure of the converter unit use equipped by controllers of a photoelectric battery and battery with independent (external) control and the possibility of charging the battery from the grid is substantiated. It expands the possibilities of energy generation and distribution control in the power supply system of a local object with several tariff zones using an intelligent energy management system in all operating modes including autonomous. The structure of the power control channel is developed, while it is possible to use a standard MPPT controller to control the generation of a photovoltaic battery. The simulation model of the system is developed. The simulation results are given. References 9, figures 4.

Keywords: photovoltaic battery, converter unit, storage battery, multi-zone tariff, power control channel, autonomous operating mode.

Introduction. Almost all electric power supply system of local objects (LO) with a renewable energy sources (RES) with the exception of autonomous electric power supply systems can be attributed to combined electric power systems (CEPS); they have connections to the AC distributed grid (DG) and receive power supply from it in the absence of RES generation. The use of such systems for LO is aimed at reducing electricity costs and increasing the reliability of power supply. In some cases the use of RES is predetermined by the presence of a limit on energy consumption (from the power system) or by the limited capabilities of the used DG. Improving the efficiency of CEPS through the use of intelligent systems of control of energy (ISCE), optimization of structures, and improvement of a converter unit (CU) is a promising direction of distributed generation development.

Problem statement. CU fulfills a key function in energy efficiency improving. It determines the generation of RES and, in the presence of a storage battery, can participate in energy redistribution in different tariff zones. The current trend is the use of multifunctional CU [1], which combines a number of functions with a power factor closed to 1 at the point of common coupling to the DG. It also provides autonomous operation mode (AOM) of LO in the absence of storage batteries (SB) [2]. Intelligent multifunctional CU are already widely marketed. There are hybrid systems [3, 4] with the photovoltaic (PV) battery, storage batteries (SB) and connection to DG. They include the use of night-time charging of the battery from the grid, followed by use during peak daytime loads, and they have a capacity of up to 10 kW, such as Growatt 10000hy [5]. The REACT 3.6 / 4.6 [6] (ABB Company) with lithium-ion batteries also provides extensive capabilities in PV generation control and load management. But it has not a charge function from the grid. These solutions are functionally completed; they have their own functioning program. At the same time, for example, it is impossible to enter the charge function from the grid or external control of the PV generation in the CU of the REACT - 3.6 / 4.6 type. This also applies to most of grid CUs for PV, which usually uses built-in MPPT controllers, which ensure PV operation in maximum power mode that excludes the possibility of external control of PV generation. This limits the possibilities of the CEPS in the AOM or with the prohibition of generation in DG. There is no possibility to connect the batteries to DG. In terms of CU using together with ISCE of LO, the "open" structure of CU is of greater interest, for example, PRO 330-TL – OUTD (ABB Company) type. At the same time, the grid voltage source inverter (VSI) has an "open" input with switching devices, current sensors and protection, which allows you to connect a PV controller and a battery charge controller with the required characteristics and external control.

Thus, the issues of generation and redistribution management of electric power in CEPS, the modification of standard CUs for the use with ICSE are insufficiently studied and need in additional research.

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The aim of the research: the development of solutions for modifying the CU structure for PV with the generation and redistribution energy management in CEPS with ICSE with the introduction of a power control channel, which will reduce power consumption from the DG and simplify the balancing of power capacities in all modes.

Research results. Proposed structure of CEPS (Fig. 1) consists of load (L1, L2, … Li), PV, SB, grid inverter (VSI). PV is connected to VSI via controller (CPV), which is regulate PV power take-off (P_{PV}), according to signal of PV voltage reference (u^*_{PV}) from the ISCE. Charge controller (CC) provides two-sided conductivity, with using the switch S it can be connected to the VSI input or through the rectifier (R) to the grid. In the case of a multifunctional VSI [2], which provides the active rectifier mode, the CC is connected directly to the VSI input (S and R are not needed and there are no current harmonics generated by a powerful rectifier). Management of S is carried out by the ISCE depending on the operating mode and the availability of PV generation. CC has a current regulator and an input of setting the charge / discharge current i^*_B of the SB. Load – LO consumers are connected to the grid through contacts (*Q1 – Qi*) with wireless control.

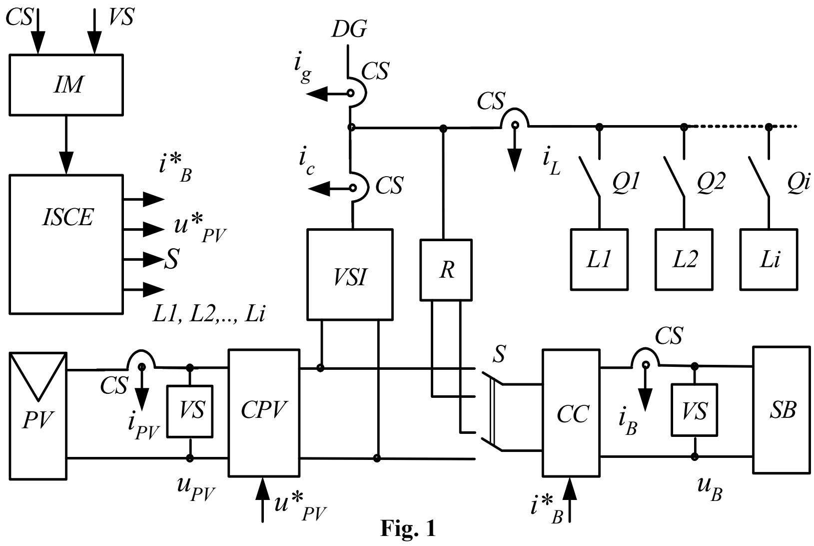

Fig. 1

Monitoring of currents and voltages in power circuits is carried out by current and voltage sensors (CS and VS on Fig. 1). The possibility of the CPV operation in the tracking mode of the maximum of the P_{PV} or the set by ICSE value P^*_{PV} is considered. A standard MPPT controller can be used if possible block it or switching-off using a relay. In this case, the regulation of energy generation to DG is carried out in relay mode: when the PV is turned off, the battery is discharged on the load; when the PV is connected, the battery is charged and receives the excess of energy. This allows you to limit (exclude) the transfer of energy in DG. This solution is connected with an increase the number of charge / discharge cycles of the SB. It is justified under implementation the autonomous mode, when there is no restriction on generation to DG in the normal mode of operation. The functions of control of the CU and the load are provided by the ISCE; information is supplied to it through the interface module (IM). IM provides the reception and transmission of signals in the system wirelessly. In addition to information from sensors, weather forecast data from the site can be entered (air temperature and cloudiness on the next day). Information for staff about the state of the system, recommendations on connecting (disconnecting) loads, warning information (including sound signals) about switching to the autonomous operation mode and about the need of transition to power saving mode with subsequent forced disconnection of secondary consumers is displayed on the screen.

The simplified structure of the channel of the power control (Fig. 2) includes: blocks of division, multiplication, adders; the unit of the SB current limitation i_B (LU) in charge and discharge mode; CC; charge degree controller (CDC); controller CPV (CCPV); unit of setting the charge current (I_{BC}) of the SB from the DG (SCU); model SB (MSB). The following variables are used: $P_{PV}=u_{PV}\cdot i_{PV}\cdot\eta_{CPV}\cdot\eta_{VSI}$, where η_{CPV}, η_{VSI} is the efficiency of CPV and VSI; P_L is the active power of load; $P_B=u_B\cdot i_B\cdot\eta_{CC}\cdot\eta_{VSI}$, where η_{CC}, η_{VSI} is the efficiency of CC and VSI; $Q=Q_0+\int i_B dt$ is the charge degree of the SB; i^*_B is the reference of the SB current; Q_S is the start charge degree of the SB on 7 a.m.; D is the determines the daily tariffication zones, if from 11 a.m. to 7 p.m. Q≥90%, then $D = 1$ from 7 a.m. to 11 p.m.; if from 11 a.m. to 7 p.m. Q <90%, then $D = 1$ (tariff zone for morning and evening maximums) from 7 a.m. to 11 a.m. and from 7 p.m. to 11 p.m.; $\overline{D}$ is the duration of the night and minimum days tariff; I_{BC} is the charge current of SB during the night; $u^*_B = u_B \cdot \eta_{CC} \cdot \eta_{VSI}$.

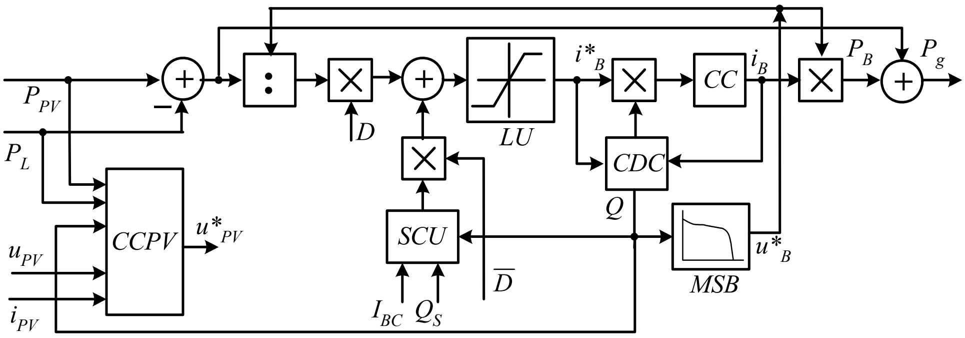

Fig. 2

Simulation in MatLab/Simulink and experimental research. Simulation of energy processes in CEPS was carried out in accordance with the structure in Fig. 2. The dependences of the daily load $P_L(t)$, solar radiation $G(t)$ were set in tabular form. The PV model uses the equation from [8]

$$I = I_{SC}\left[1-\left(1-I_M / I_{SC}\right)^{\frac{U-U_{OC}}{U_M-U_{OC}}}\right],$$

where $I_{SC}=WI_{SCd}$, $I_M=WI_{Md}$, U_{OC}, U_M are the PV current and voltage for short circuit mode (sc), maximum power (M), open circuit mode (oc), data sheet values (d); $W= G/1000$.

For simplifying the temperature of the photo module is taken equal to the data sheet value and, accordingly, $U_{OC}=U_{OCd}$, $U_M=U_{Md}$. Tracing of the maximum point P_{PVMAX} and $P_{PV}=P^*_{PV}$ ($P^*_{PV} = P_L + P_{gL}$ is the reference value, P_{gL} is the limit of the power which is generate in DG, $P_{gL}=0$ in autonomous mode) is carried out by known methods [9]. Switching to the regulation mode of PV generation is carried out at Q≥95%.

The average daily value P_{LAV}=5 kW, P_{LMAX} = 9.125 kW, W_L = 120 kW · h. The rated PV power is selected based on the average monthly generation in June [7] under the condition $P_{PVAV} \approx P_{LAV}$. The battery capacity was selected from the condition $P_B=P_{PV}$ (in [3] the ratio 4:1, in [4] – 1:2).

Oscillograms P_{PV}, P_L, P_g and Q for a clear June day are shown in Fig. 3: without limitation PV generation (Fig. 3, *a)* and at P_{gL}=0 (Fig.3, *b*). On Fig. 3, *c* the implementation P_{gL}=0 with relay control of P_{PV} is shown. To a cloudy day (reduction P_{PV} half) corresponds to Fig. 4.

The possibility of AOM realization with relay control of P_{PV} is confirmed at an experimental set up with hybrid VSI type «AXIOMA energy» (3 kVA) with built-in MPPT controller and charge controller.

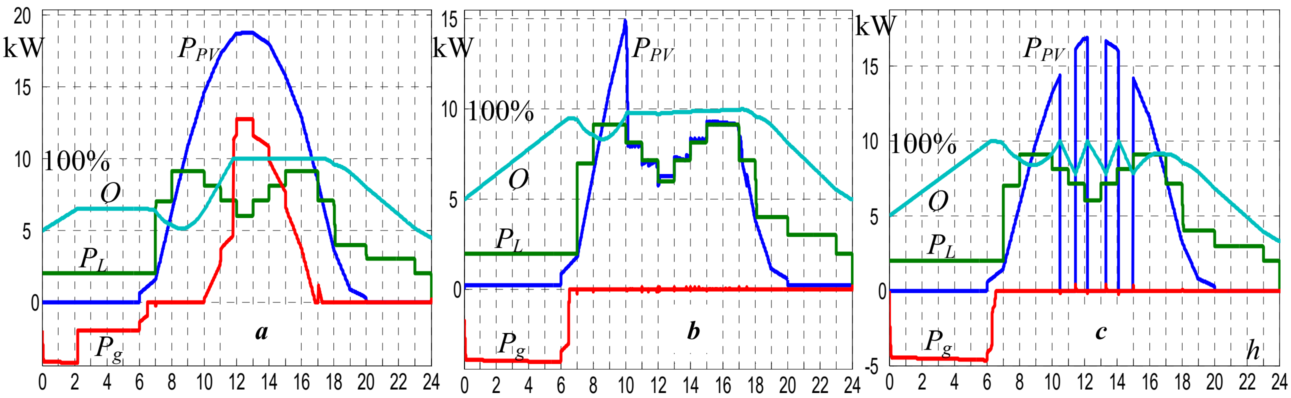

Fig. 3

Conclusions. The energy management and redistribution system in CEPS of LO has been improved for the CU structure with external control of the PV and SB controllers by introducing a control channel of the system's power, which carries out the battery charge / discharge control and when needed the regulation power take-off of PV. The set values of the battery current and the voltage of the PV are formed by the ISCE. The possibility of implementation of PV generation regulation using a standard MPPT controller is shown. Battery charge from DG is carried out at the night tariff, or, if necessary, during the times of the minimum days tariff. The degree of charge can be adjusted depending on the load schedule and weather forecast for the next day, which gives an additional reduction in energy consumption. Even on cloudy days, it is possible to compensate for morning and evening load peaks. Further development of the work involves the study of issues of the direct use of the weather forecast data by ISCE. This is necessary for the formation of a recommended load schedule for the next day in normal mode and during the operation of LO in the autonomous mode with sufficient degree of charge of the battery to ensure minimum consumption until the next daylight hours.

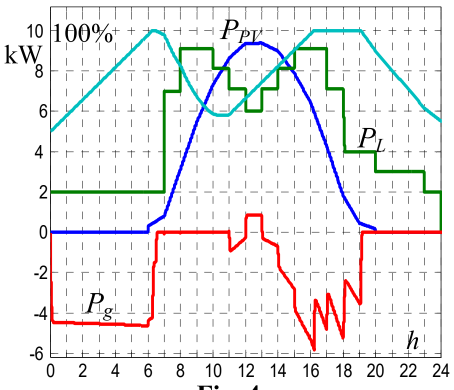

Fig. 4

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УДК 621.314.26

УПРАВЛІННЯ ГЕНЕРАЦІЄЮ ТА ПЕРЕРОЗПОДІЛОМ ЕЛЕКТРОЕНЕРГІЇ В ПІДКЛЮЧЕНІЙ ДО МЕРЕЖІ ФОТОЕЛЕКТРИЧНІЙ СИСТЕМІ ЛОКАЛЬНОГО ОБ'ЄКТУ

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Розглянуто підключену до мережі фотоелектричну систему локального об'єкту з акумуляторною батареєю у разі використання мережевого інвертора з «відкритим» входом. Обґрунтовано доцільність використання структури перетворювального агрегату з комплектацією його контролерами фотоелектричної батареї та акумулятора з незалежним (зовнішнім) управлінням і можливістю заряджання акумулятора від мережі. Стосовно до мереж з декількома тарифними зонами це розширює можливості щодо управління генерацією та розподілом енергії в системі електропостачання локального об'єкту під час використання інтелектуальної системи управління енергоспоживанням у всіх режимах роботи, включаючи автономний. Розроблено структуру *каналу управління потужністю, за цих умов передбачено можливість використання стандартного MPPT контролера задля управління генерацією фотоелектричної батареї. Розроблено імітаційну модель каналу управління потужністю. Наведено результати моделювання.* Бібл. 9, рис. 4.

***Ключові слова**:* фотоелектрична батарея, перетворювальний агрегат, акумуляторна батарея, багатозонний тариф, канал управління потужністю, автономний режим роботи.

УДК 621.314.26

УПРАВЛЕНИЕ ГЕНЕРАЦИЕЙ И ПЕРЕРАСПРЕДЕЛЕНИЕМ ЭЛЕКТРОЭНЕРГИИ В ПОДКЛЮЧЕННОЙ К СЕТИ ФОТОЭЛЕКТРИЧЕСКОЙ СИСТЕМЕ ЛОКАЛЬНОГО ОБЪЕКТА

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Рассмотрена подключенная к сети фотоэлектрическая система локального объекта с аккумуляторной батареей при использовании сетевого инвертора с «открытым» входом. Обоснована целесообразность использования структуры преобразовательного агрегата с комплектацией его контролерами фотоэлектрической батареи и аккумулятора с независимым (внешним) управлением и возможностью заряда аккумулятора от сети. Применительно к сетям с несколькими тарифными зонами это расширяет возможности управления генерацией и распределением энергии в системе электроснабжения локального объекта при использовании интеллектуальной системы управления энергопотреблением во всех режимах работы, включая автономный. Разработана структура канала управления мощностью, при этом предусмотрена возможность использования стандартного MPPT контроллера для управления генерацией фотоэлектрической батареи. Разработана имитационная модель канала управления мощностью. Приведены результаты моделирования. Библ. 9, рис. 4.

***Ключевые слова**:* фотоэлектрическая батарея, преобразовательный агрегат, аккумуляторная батарея, многозонный тариф, канал управления мощностью, автономный режим работы.

Надійшла 28.02.2020
Остаточний варіант 24.04.2020