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T. Sobczyk, PhD, DSc
W. Mazgaj, T. Wegiel, PhD
L. Kopchak, B. Kopchak, PhD
R. Jacukowicz, M. Twerd, MSc

POWER ELECTRONIC CONVERSION SYSTEM FOR SMALL POWER PLANTS BASED ON RENEWABLE SOURCES

Abstract *Quite often energy in small wind and water plants is produced by PM synchronous generators which work at variable rotational speed. This energy has to be converted by means of a power electronic unit to fit to the three-phase power grid parameters. The main purpose of the control strategy is to transfer maximum possible amount of energy to the power grid.*

Т. Собчік ., доктор філософії
Б.Л.Копчак , Л.С.Копчак , В. Мазгай , Т. Вугіль , кандидати технічних наук
Р.Джакукович ., М.Тверд

ПОТУЖНІСТЬ ЕЛЕКТРОННОГО ПЕРЕТВОРЕННЯ СИСТЕМА ДЛЯ МАЛИХ ЕЛЕКТРОСТАНЦІЙ НА ОСНОВІ ПОНОВЛЮВАНИХ ДЖЕРЕЛ

Анотація. *Все частіше енергія в малих вітро- і гідроелектростанціях генерується синхронними генераторами з постійними магнітами, які працюють із змінною швидкістю обертання. Ця енергія повинна бути перетворена за допомогою електронного блоку, потужність якого відповідає параметрам трифазної енергосистеми. Основна мета стратегії керування полягає в передачі максимально можливої кількість енергії до електричної мережі.*

Т.Собчик, доктор философии
Б.Л. Копчак , Л.С. Копчак, В. Мазгай , Т. Вугиль , кандидаты технических наук
Р. Джакукович , М.Тверд

СИСТЕМА ПИТАНИЯ ЭЛЕКТРОННОЙ КОНВЕРСИИ ДЛЯ РАСТЕНИЙ МАЛОЙ МОЩНОСТИ НА ОСНОВЕ ВОЗОБНОВЛЯЕМЫХ ИСТОЧНИКОВ

Аннотация.*Все чаще энергия в малых ветро- и гидроэлектростанциях генерируется синхронными генераторами с постоянными магнитами,* которые работают *с переменной скоростью вращения. Эта энергия должна быть преобразована с помощью электронного блока, мощность которого соответствует параметрам трехфазной энергосистемы.* Основная цель *управления состоит в передаче максимально возможного количества энергии в электрические сети.*

Electrical generators for today's small wind and hydro power-plants are designed for a constant rotational speed, which is kept by a speed controller often consisting of mechanical equipment. Changes of energy provided by wind or water depend on wind force and water flow, which are very unreliable quite often. Therefore, full efficiency can be achieved for power technology with generators, especially permanent magnets (PM) generators, working at variable speed. This leads to an essential simplification of mechanical systems but this in turn requires an application of a power electronic unit in electrical system. This power electronic unit has to be applied not only to ensure the output frequency and voltages required by the power grid, but also to control the energy flow from generator to the three-phase grid [2,3,5,6,7].

The fundamental purpose of the control strategy is to transfer maximum possible amount of energy, produced by the PM generator, to the power grid. On average the rms voltage and the frequency of the PM generator can change about ± 50% with respect to the nominal values. In the power electronic conversion system energy produced by the generator is converted into direct current energy (DC link), and then it is transferred to power grid via voltage source inverter [4,8]. In practice, two schemes of energy conversion are used, especially with reference to wind turbine.

The first one is based on an uncontrolled rectifier and DC-DC converter which can increase DC voltage (Fig. 1), and in the second one a pulse-width modulation (PWM) rectifier is applied (Fig. 2). In both cases, the

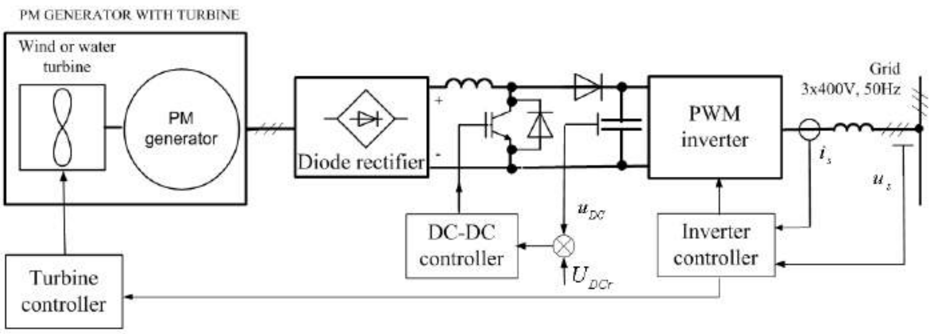

Fig.1. Power electronic unit with the diode rectifier and the DC-DC converter: *UDCr* – assumed voltage of the DC link, *is* – output current of the PWM inverter, *us* – voltage of the power grid

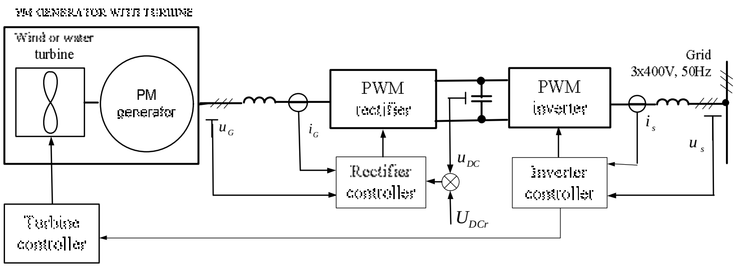

Fig.2. Power electronic unit with the PWM rectifier: uG, iG, – voltage, and current of the PM generator

voltage source inverter is coupled with power grid using transformer or induction chokes, which are necessary for correct working of the energy conversion system. The first method of energy conversion is quite rarely applied, and it is not recommended because the diode rectifier can cause significant distortion of the generator currents with respect to sinusoidal shapes.

As a result of this distortion the generator torque contains an alternating component with relatively high amplitude [9]. It is a certain disadvantage since the presence of this alternating component of the torque can significantly influence durability and reliability of the turbine - generator unit. In this case, we do not have the possibilities to decrease directly the amount of higher harmonics of the PM generator current. An application of the PWM rectifier results in almost sinusoidal shapes of the generator currents, so it enables to reduce alternating component of PM generator torque.

On the one hand, the control method has to ensure the highest efficiency of whole energy conversion system. However, on the other hand, the control algorithm, especially algorithm of transistor switching, should limit the amount of higher harmonics of the current which flows to the 3 x 400 V, 50 Hz power grid. It is also desirable that the PM generator current should have relatively low the Total Harmonic Distortion factor. It guarantees that the alternating component of the PM generator torque has a low value.

The energy amount, which is transferred to the power grid, can be lowered if power consumption in grid decreases. The similar situation can occur if wind or hydrological conditions become worse, which means that the wind force or water stream flowing reduces. The control system was worked out by "TWERD" Power Electronics Company in Torun (Poland). In this control system (Fig. 3) [1] the power grid is treated as an induction motor which works at constant rotational speed.

The algorithm of direct power control with a feedback of virtual flux (VF-DPC) is based on a closed-loop feedback of active and reactive power. The power amount, which should be transferred to the DC link is adjusted by means of the proportional-plus-integral controller. The assumed active power p_{ref} and reactive power q_{ref} are compared with actual values of both kinds of power. Differences between assumed and actual values are input values of *p* and *q* controllers. Outputs of these controllers are the given signals for the SVM modulator.

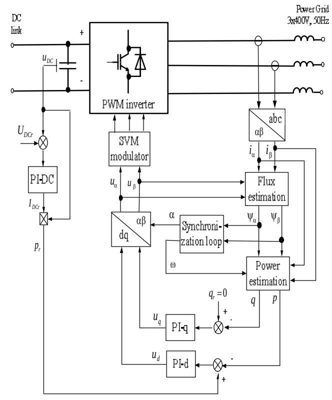

Fig.3. Block-diagram of VF - DPC control algorithm

The virtual flux (similarly as in AC drives) is inserted into feedback in order to improve the parameters of control system. The measured current values and estimated virtual flux are used to calculate the active and reactive actual values. In the proposed control system it is not necessary to measure phase voltages. This system is also jam-proof because the flux acts as a low-pass filter. The PWM rectifier in the second system of energy conversion is controlled similarly as it is shown above, and in this case two generator currents are measured.

Research was made in the Institute of Electromechanical Energy Conversion in Cracow University of Technology. A designed 3-phase PM generator for application in experimental power station have the nominal data: P_N = 30 kW, U_N = 500 V, I_N = 34.7 A, f = 50 Hz, n_N = 600 rpm, p = 5. The residual flux density of the generator permanent magnets is equal to 1,2 T, and coercive force 891 kA/m. Figure 4 presents the outward look of power electronic conversion system worked out by "TWERD" Power Electronics Company, enabling to conduct research on both methods of energy conversion (Fig.1, Fig.2). Research was carried out for both systems of energy conversion for different as summed RMS values of the current flowing to the power grid. These energy conversion systems work correctly also in transient states, which may occur during changes of the wind or water conditions.

Fig.4. Power electronic conversion system (P=30 kWt) worked out by "TWERD" Power Electronics Company

Figure 5 presents waveforms of the PM generator and the PWM inverter currents in the power electronic unit with DC-DC converter, and the next figure includes the similar waveforms recorded in the energy conversion system with PWM rectifier.

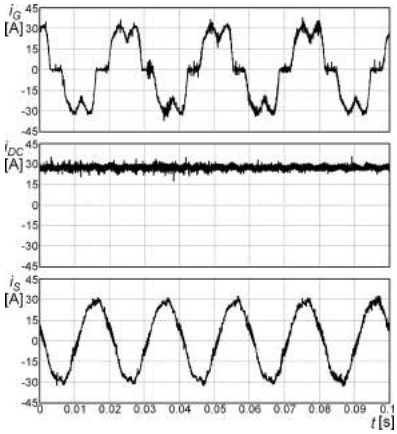

Fig.5. Current waveforms in the conversion system with the DC-DC converter: i_G - generator current, i_{DC} - current in the DC link, i_s - PWM inverter current

During current recording the PM generator rotated at 450 rpm, and in this connection the frequency of the generator current was equaled 37.5 Hz. Energy conversion by means of the PWM rectifier positive influences the generator currents (Fig. 6), because these currents are closer to sinusoidal shape unlike the generator current shape with the use of the DC-DC converter.

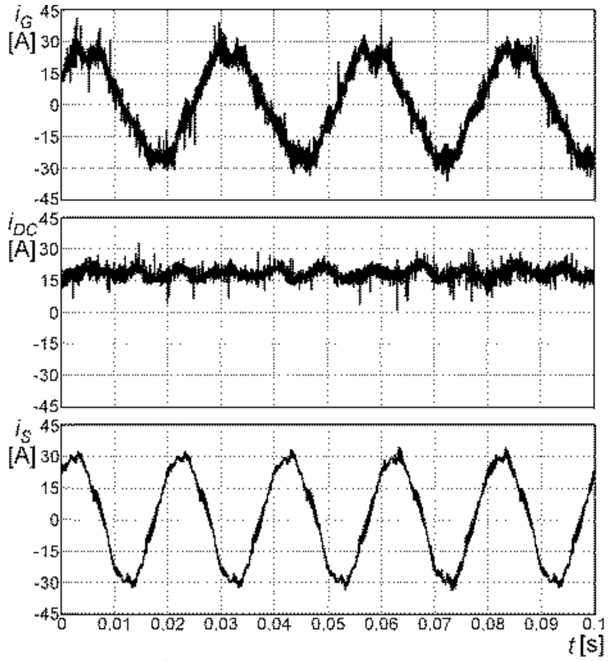

Fig.6. Waveforms in the conversion system with the PWM rectifier: i_G – generator current, i_{DC} - current in the DC link, i_s – PWM inverter current

The second one of the presented energy conversion systems (Fig. 2) is better due to lower distortion of the PM generator currents. The proposed control algorithm, which has been applied in the power electronic unit, has some advantageous in comparison with conventional conversion systems. First of all, in this control method the active and reactive currents have not to be decoupled, and this algorithm is easy to implement in small wind and water power plants. Additionally, there is no need to measure the phase voltages, and the carried out measurements show that the Total Harmonic Distortion factor of the PM generator current has lower value in the energy conversion system with the PWM rectifier.

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Sobchyk Tadeush, Prof., PhD, DSc, Director of the Institute on Electromechanical Energy Conversion, Cracow University of Technology, ul. Warszawska 24, 31-155 Kraków, Poland, phone: +48 12 628 26 14, e-mail: pesobczy@cyfronet.pl

Mazgaj Witold, PhD, Assistant professor, Cracow University of Technology, Institute on Electromechanical Energy Conversion, ul. Warszawska 24, 31-155 Kraków, Poland, phone: +48 12 628 26 99, e-mail: pemazgaj@cyfronet.pl

Wegiel Tomasz, PhD, Assistant professor, Cracow University of Technology, Institute on Electromechanical Energy Conversion, Warszawska 24, 31-155 Kraków, Poland, phone: +48 12 628 26 21, e-mail: pewegiel@cyfronet.pl

Kopchak Bogdan Lyubomyrovych, PhD, Associate Professor, Lviv Polytechnic National University, Institute of Energetics and Control Systems, Lviv-13, Bandery Str 12.,Ukraine, phone: 258-21-60
E-mail: kopchak@mail.ru

Kopchak Lyubomyr Stefanovych, PhD, Associate Professor, Lviv Polytechnic National University, Institute of Energetics and Control Systems, Lviv-13, Bandery Str 12.,Ukraine, phone: 258-21-26
E-mail: kopchak@mail.ru

Mihal Twerd, MSc, director "TWERD" Power Electronics Company, ul. Konwaliowa 30, 87-100 Torun, Poland, phone: +48 56 654 60 91, e-mail: twerd@twerd.pl

Rafal Jacukowicz, MSc, senior specialist in energetic electronics "TWERD" Power Electronics Company, ul. Konwaliowa 30, 87-100 Torun, Poland, phone: +48 56 654 60 91, e-mail: twerd@twerd.pl