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Simulation of the operation of a voltage inverter as part of an autonomous wind power plant with aerodynamic multiplication based on an asynchronous generator with a phase rotor

Hlib Strunkin*

Master
Engineering Institute of Zaporizhzhia National University
69006, 226 Sobornyi Ave., Zaporizhzhya, Ukraine
https://orcid.org/0009-0009-1719-4132

Abstract. In the context of energy scarcity caused by the destruction of energy infrastructure, instability of electricity supply and growing demand for autonomous energy sources, there is a need to develop independent and efficient energy supply systems. Of particular importance are wind power plants that are able to function independently, ensuring the stability of power supply even in crisis conditions. In this regard, it is important to investigate promising solutions that meet modern quality standards and can integrate into autonomous energy systems. The purpose of the study was to confirm the efficiency of calculating inverter filters in static and dynamic modes, and under unbalanced load conditions. This was achieved on the basis of simulation modelling of an autonomous wind power plant with aerodynamic multiplication operating on the basis of an asynchronous generator with a phase rotor and excitation from a voltage inverter. A simulation model of an autonomous wind power plant and inverter parameters calculated according to the author's methods in the PSIM environment were described. A Fourier analysis of the harmonic composition of the output voltage of the inverter was performed programmatically, and its harmonic coefficient, which did not exceed 5%, was calculated in accordance with the current standard. It was proved that the excitation from the voltage inverter improves its operation under unbalanced load and release and surge. The results of modelling the output voltage of the inverter were compared with the requirements of standards for continuous power sources. Based on the results of simulation modelling of an autonomous wind power plant with aerodynamic multiplication, the efficiency of calculating voltage inverter filters for an asynchronous generator with a phase rotor was confirmed. The methods have shown their effectiveness both in static and dynamic modes, and under conditions of unbalanced load

Keywords: stand-alone voltage inverter; load release and surge; unbalanced load; harmonic ratio; simulation

Introduction

The modern energy sector is in a state of rapid change and faces a number of challenges, including military operations, rising energy prices, and difficulties of their transportation. In these circumstances, the development of renewable energy sources is not only important, but also critically necessary. Wind power, as one of the most promising industries, offers efficient solutions for autonomous energy supply. In particular, autonomous wind power plants (WPPs) are becoming increasingly relevant, given their ability to operate independently of centralised systems.

The Ukrainian energy sector is facing new challenges related to military operations, the cost of energy carriers and the complexity of their delivery. As reported by the Prime Minister of Ukraine D. Shmyhal (2024), "The number one issue is energy." In his speech, he stressed that the greatest attention should be paid to the development of alternative and renewable energy. In remote farms, according to A. Konechenkov *et al.* (2022) the use of wind energy through autonomous wind power plants (WPPs) may be promising.

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*Corresponding author

O.V. Nemykina (2020) focused on the development of multiplier-free circuits for wind power plants. The author noted that the use of such circuits can reduce energy losses during the transmission of mechanical power, while reducing the level of wear of components. However, the researcher pointed out the need for a more detailed study of the durability of materials used in such systems, especially in autonomous operation. C. Anderson (2020) analysed the efficiency of direct-drive WPPs compared to conventional models. He noted that this design reduces technical losses and increases the stability of installations under variable weather conditions. However, the researcher noted the problem of insufficient consideration of the specifics of autonomous conditions, in particular, the impact of wind flow instability on energy generation.

Ukrainian researcher V.V. Klymenko *et al.* (2023) investigated the possibilities of integrating aeromechanical equipment into the design of autonomous WPPs. He stressed that the use of such solutions can significantly increase the capacity of installations. However, the study did not cover modelling the operation of wind turbines under non-standard conditions, which creates a gap in the development of autonomous systems. R. Ranjan *et al.* (2023) investigated the environmental aspects of wind turbine use. They noted that the introduction of new technologies to reduce oil leaks can significantly reduce the negative impact on the environment. Moreover, the researchers acknowledged that further research should focus on integrating environmentally friendly solutions into the design of autonomous WPPs.

Ukrainian researchers P. Olczak & T. Surma (2023) considered modern approaches to improving the element base of wind power plants. They noted that the development of new materials and technologies allowed reaching the capacity of autonomous WPPs up to 1,000 MW, but stressed the need for a detailed study of the reliability of these systems during long-term operation.

J. Paul *et al*. (2018) analysed the problems of reducing the noise impact of wind turbines. The authors noted that noise reduction is an important aspect for the use of standalone wind turbines in residential areas. However, the researchers emphasised the lack of a comprehensive approach to assessing acoustic characteristics in relation to the efficiency of electricity generation. M.S. Golubenko *et al*. (2008) considered the prospects of using aerodynamic multiplication (AM) in wind power systems of WPPs. The author pointed out the significant potential of this technology to increase the capacity of installations, but noted that its application in autonomous systems requires additional research.

In the UK, teams led by P. Jamieson (2020) and L. Morgan *et al.* (2022; 2024) conducted a study of wind turbines with a vertical axis of rotation, emphasising their advantages in urban environments. However, according to the researchers, these installations have limited potential for autonomous systems due to their low stability in variable wind conditions.

The purpose of this study was to perform calculations and modelling of autonomous wind power plants with aerodynamic multiplication to confirm their compliance with the requirements of standards for uninterruptible power supplies, which apply to such systems at the design stage.

Materials and Methods

To achieve this purpose, the paper used simulation modelling methods in the PSIM (2021) environment, which was designed for modelling power electronics devices, electromechanical systems, alternative energy facilities, power sources, etc. The parameters for the simulation model were calculated using the methodology developed by the author under the guidance of A.V. Pereverzev *et al.* (2006; 2007) for selecting the elements of input and output filters and setting up the automatic control system. Due to the fact that the simulation results were obtained in the form of dynamic characteristics of controlled parameters, statistical processing of the obtained data was not provided. Fourier analysis of the PSIM software suite was used to investigate the harmonic composition of the output voltage. The study was carried out at the Pluton IC LLC (Zaporizhzhia), where the developed methods for calculating inverter filters and the built mathematical model were used. These methods were implemented when creating a guaranteed power supply system for SGE-50-380-2-1-30-UHL4, which was confirmed by the relevant implementation report.

A special feature of WPPs with ADM was the installation of small high-speed secondary wind turbines on the blades of a large primary wind turbine (Fig. 1), which, rotating under the action of the primary wind flow, created a secondary wind flow of significant speed for secondary wind turbines. This allowed the secondary wind turbine to drive the generators without using a multiplier.

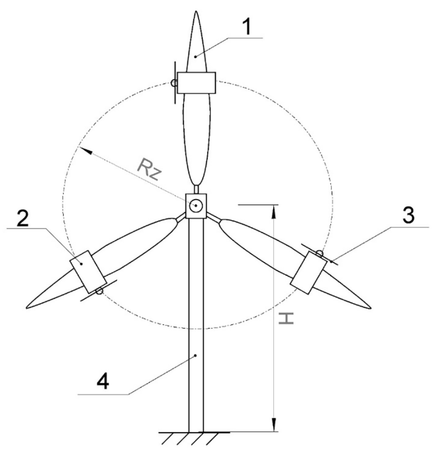

***Figure 1**. Diagram of a wind turbine with ADM*

***Note:** 1 – blades of the primary wind turbine; 2 – nacelle with generator and electrical equipment; 3 – secondary wind turbines; 4 – support; Rz – radius of fixing the secondary wind turbine; H – height of the axis of the primary wind turbine*

***Source:** developed by the author based on M.S. Golubenko et al. (2008)*

One of the possible approaches to controlling the power of such a wind turbine was to install a frequency converter (FC) in the generator circuit. With the use of asynchronous phase rotor generators (APRG), the installed power of such an FCF can be reduced as indicated by G. Abadi *et al.* (2011). Figure 2 shows a block diagram of an autonomous WPP with ADM based on APRG.

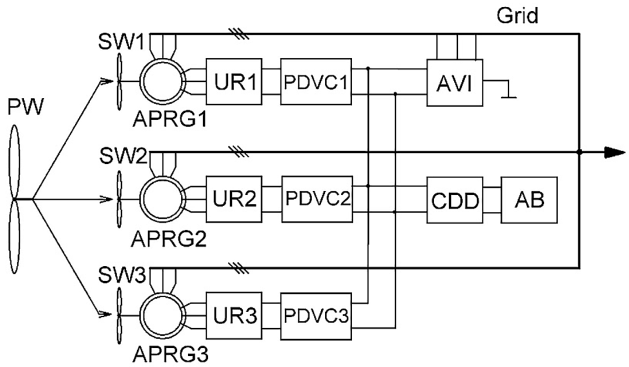

***Figure 2**. Diagram of an autonomous WPP with ADM based on APRG*

***Note:** PW – primary wind turbine, SW1...SW3 – secondary wind turbines, APRG1...APRG3 – asynchronous phase rotor generators, UR1...UR3 – uncontrolled rectifiers, PDVC1...PDVC3 – pulsed DC voltage converters, AB – battery, CDD – charging and discharging device, AVI – autonomous voltage inverter*
***Source:** developed by the author*

In the presence of wind, the primary wind turbine created a wind flow for secondary wind turbines SW1...SW3, which were located on the PW blades, which, in turn, rotated asynchronous generators with a phase rotor APRG1... APRG3. Energy was removed both from the stator side of each generator and from the rotor side (sliding energy) through an individual uncontrolled rectifier UR1...UR3. When the wind speed exceeded the rated speed, or there was a local speed imbalance, it was possible to reduce the moment by adjusting the counter-EMF of the pulsed DC voltage converter PDVC1...PDVC3, which was the load of uncontrolled rectifiers. Sliding energy was also used to recharge the AB battery. The AB charging current was formed by the CDD charging and discharging device. The autonomous voltage inverter AVI formed a network and compensated for the reactive power of the generators. In the event of wind start-up or absence, the necessary energy was provided by the AB.

The parameters for the simulation model were calculated for the power of an autonomous WPP with ADM of 750 kW at a rated primary wind flow rate of 11 m/s, which was similar to the existing TG-750 wind turbine built by M.S. Golubenko *et al.* (2008). The parameters of the input, output filters, and control system of the inverter are calculated according to the author's method (Pereverzev *et al.*, 2006; 2007) to check the adequacy of the operation of an electromechanical system of an autonomous WPP with ADM based on an asynchronous generator with a phase rotor excited by a voltage inverter. According to Figure 2, the simulation model was divided into its component parts: a model of a wind turbine with an ADM, 3 asynchronous generators with a phase rotor, 3 unmanaged rectifiers, 3 pulsed DC voltage converters, a charging and discharging device, an autonomous voltage and load inverter. Due to the use of the MTH-713-10 crane engine manufactured by Sealocean (China) as a generator, the phase voltage of the network was reduced within the standard (minus 15% of the rated value) to 192V to reduce the magnetisation current.

Results and Discussion

The simulation model, as described earlier, is divided into its component parts. The construction and parameters of these components are described in more detail below.

1. Stand-alone voltage inverter.

The transistors of the inverter are assembled in a three-phase bridge circuit with a zero wire, which is connected to the midpoint of the input capacitance. Bridge (Fig. 3) was modelled using 6 bipolar transistors with an insulated-gate bipolar transistor (IGBT), the parameters of which include the values of saturation voltage – 1.5 V and dynamic resistance – 1 mOhm, and, respectively, 0.7 V and 1 mOhm – for the reverse diode.

The input filter is constructed using a capacitive divider with a total capacity of 40 mF. Each divider capacitor is shunted by a 10 kOhm discharge resistor. Each phase of the inverter had an L-shaped LC filter with an inductance of 0.14 mH and a capacitor of 460 uF. The output filter capacitor is also shunted by a 10 kOhm discharge resistor. The AVI had a current sensor with a factor of 1/1,500 and a voltage sensor with a factor of 1/310 in each phase. At the output of each sensor, a low-pass filter with a cutoff frequency of 100 Hz is turned on to filter interference.

The inverter control system is built in the form of a sub-circuit (Fig. 4) and was a dual-circuit subordinate automatic control system. Internal circuit – current with PI regulator (proportional part-10, integral part – 0.33 ms). External circuit – by voltage with a PI regulator (proportional part – 2, integral part – 5 ms). The problem is a sinusoid with a corresponding angle for each phase (0, 120, and 240 degrees).

From the output of the current regulator, the signal was sent to the PWM pulse-width modulation unit, which is implemented on comparators. PWM was obtained by comparing the signal from the regulator with a sawtooth signal with a frequency of 3 kHz. The control signal for the lower transistor of the rack is obtained by inverting the control signal for the upper transistor.

2. Description of the model of an asynchronous generator with a phase rotor.

A standard model of an asynchronous machine with a phase rotor from the PSIM model library was used for modelling. In the window for entering APRG parameters, the parameters of the MTH-713-10 crane engine replacement scheme are entered.

3. Description of the model of WPP with ADM

The WPP with ADM model proposed by D.G. Alekseevskiy (2020) was used for simulation modelling. Figure 5 shows a model of a primary wind turbine and a single channel of aerodynamic multiplication of a secondary wind turbine.

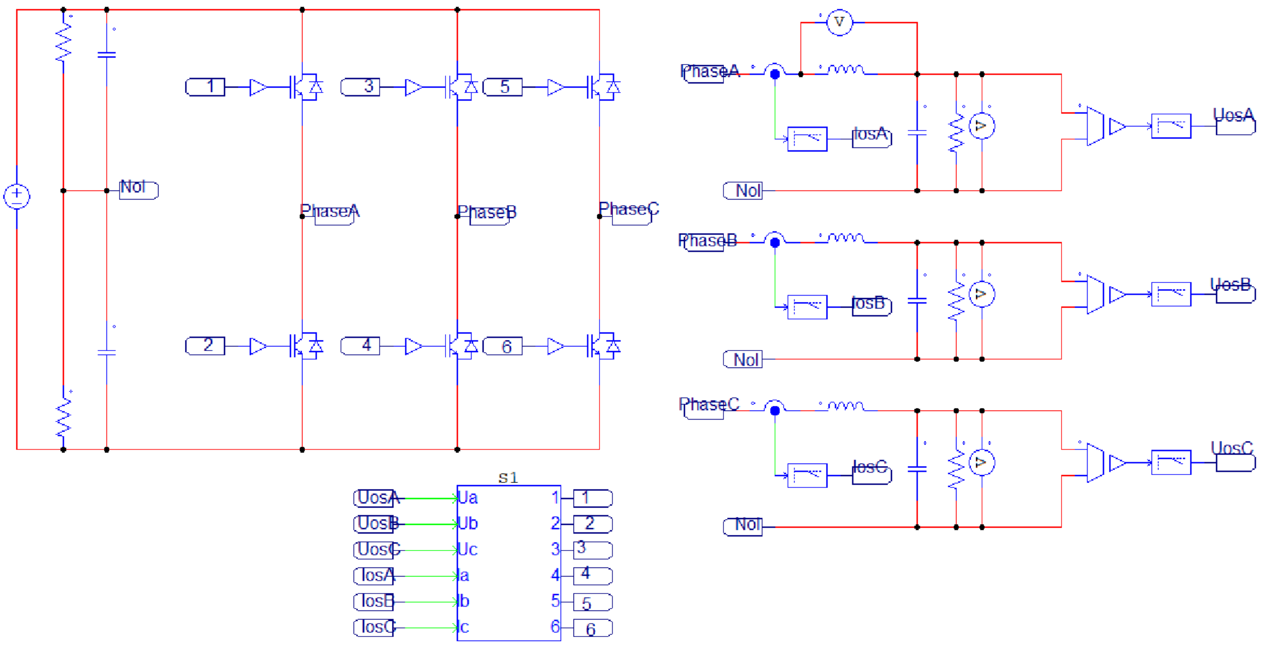

***Figure 3**. Stand-alone voltage inverter model*

***Source:** developed by the author*

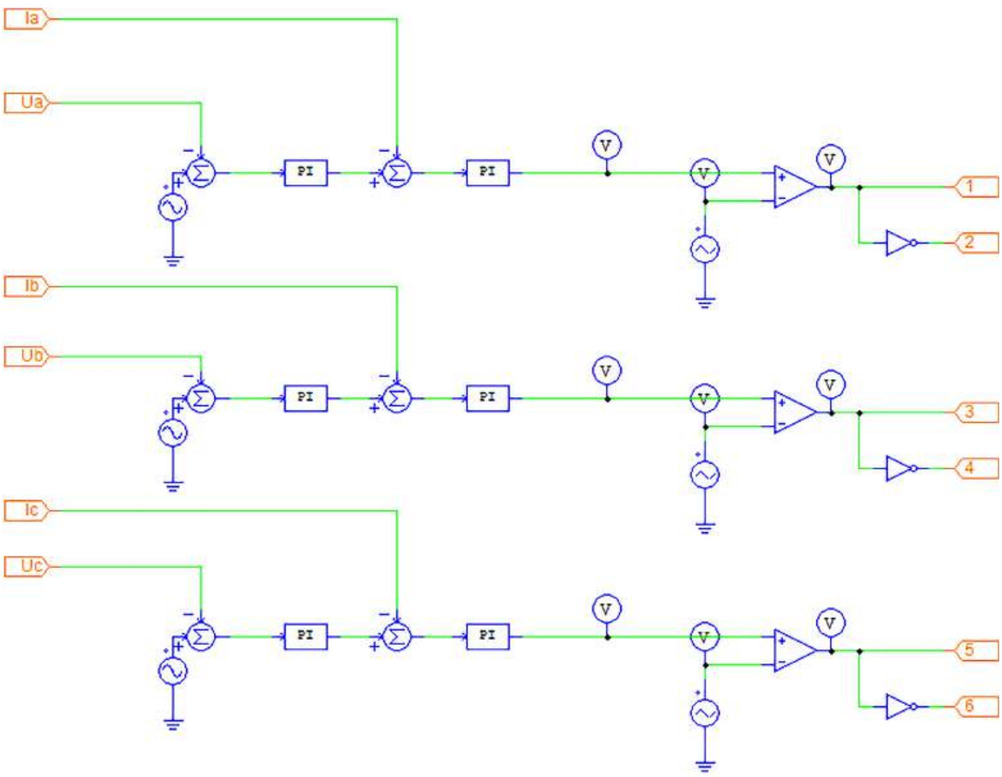

***Figure 4**. AVI management system model*

***Note:** Ia, Ib, Ic – input terminals of current feedback signals; Ua, Ub, Uc – input terminals of voltage feedback signals; Pi – proportional-integral regulator; 1...6 – output terminals of IGBT control signals*

***Source:** developed by the author*

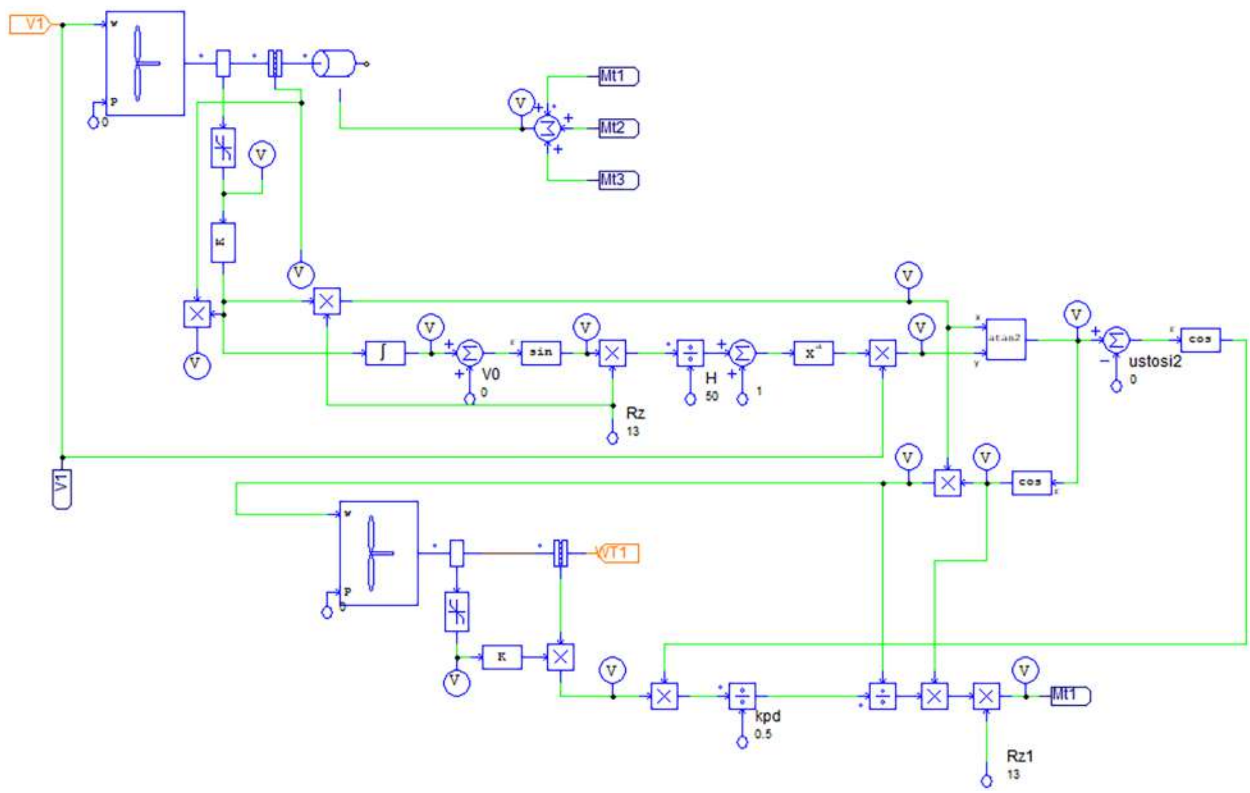

***Figure 5**. Model of WPP with ADM*
***Note:** V1 – input terminal and communication of the primary wind flow velocity signal; Mt1...Mt3 – communication by moments of secondary wind turbines; wt1 – output terminal of the signal of the angular velocity of rotation of the secondary wind turbine*
***Source:** developed by the author based on D.G. Alekseevskiy (2020)*

Standard wind wheel models from the PSIM library are used to model primary and secondary wind turbines. The parameters of the models were calculated using a similar wind turbine – TG-750 developed by M.S. Golubenko *et al.* (2008). The primary turbine had a rated power of 750 kW with a primary wind flow rate of 11 m/s and a rated rotation speed of 16 rpm. The secondary wind turbine had a rated power of 250 kW at a secondary wind flow rate of 21 m/s and a rated rotation speed of 1,200 rpm, which corresponded to the sliding of the APRG s = -1.

The speed of the primary wind flow was set to the input pin V1. Torque and angular velocity sensors are installed on the wind turbine shaft, after multiplying the signals from which power is obtained. Further, the path from the integrator to the arctangens input implemented a block for calculating the dependence of the wind flow rate on the position of the primary wind turbine blade. The resulting value, considering the angle of installation of the secondary wind turbine axis, is used as the secondary wind flow. The output contact from the secondary wind turbine is WT1, which is connected to the generator axis. The calculated power value of the secondary wind turbine allows estimating the braking moment of the secondary wind turbine. The value of the braking moment of all secondary wind turbines MT1, MT2, MT3 is algebraically summed with the moment of the primary wind turbine.

4. Model description of unmanaged rectifier and pulsed DC voltage converter.

Figure 6 shows the APRG and its rotary circuit consisting of an uncontrolled rectifier and a pulsed DC voltage converter of the step-up type. The unmanaged rectifier represents a three-phase diode bridge rectifier. The PDVC is constructed using an IGBT model similar to that used in the AVI. The cumulative inductance was 0.4 mH. The PDVC output is connected to the AVI input. To set the angular velocity on the APRG shaft, a single-circuit automatic control system with a PI regulator is constructed (proportional part – 1, integral part – 10 ms). The angular velocity control task was applied after calculating the optimal value (Kumar & Chatterjee, 2016). The output of the angular velocity controller is connected to a PWM unit with a switching frequency of 1 kHz.

A three-phase wattmeter is installed in the rotary and stator circuits to measure active power.

5. Description of the charger and battery model.

Considering that the task of the CDD, in addition to ensuring the appropriate operation of the battery, to stabilise the voltage in the DC link (on the input filter of the AVI), it is modelled as an EMF source of 610 V with an internal resistance of 1 mOhm, corresponding to the external characteristic of a pulsed DC voltage converter. This approach was considered appropriate, considering that the PDVC as part of the CDD is covered by feedback on the voltage of the DC link. To monitor the energy that the CDD gave or consumed, a wattmeter is installed to measure the active power. The AB charge corresponded to a positive power value, and the discharge – to a negative one.

The operation of the AVI in steady-state mode is modelled, when the primary wind flow speed was 11 m/s, and the load power was 750 kW. The shape of the output voltage is observed, which is shown in (Fig. 7).

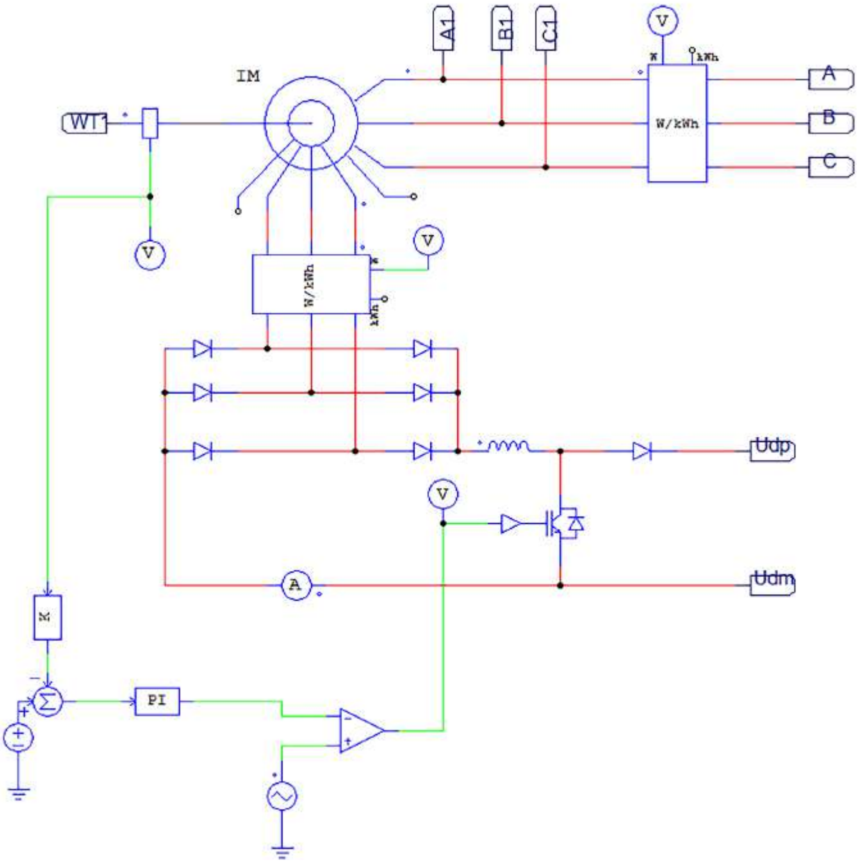

Figure 6. *Model of APRG and its rotary chain*

Note: *wt1 – output terminal of the secondary wind turbine angular velocity signal; Udm, Udp – terminals "+" and "-" of the DC circuit; A1, B1, C1 – mains voltage connections*

Source: *developed by the author*

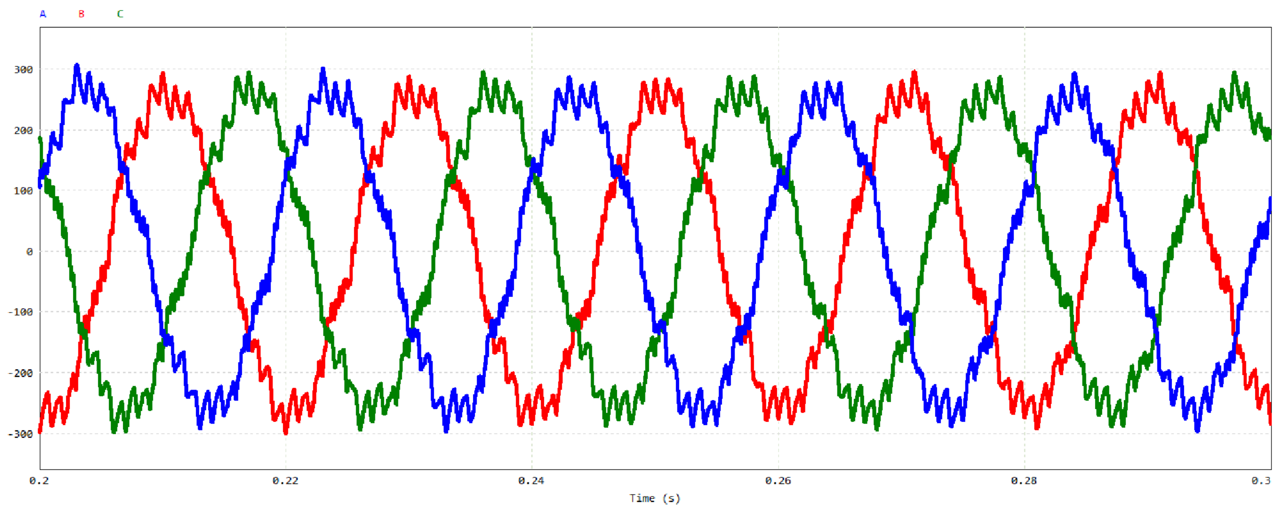

Figure 7. *Results of modelling the shape of the output voltage of the AVI in steady-state mode*

Source: *developed by the author*

Thus, the output voltage is characterised by a relatively high degree of symmetry between the phases. To estimate the high-frequency component, a harmonic analysis was performed, the results of which are shown in Figure 8 and the harmonic coefficient of the inverter voltage was calculated.

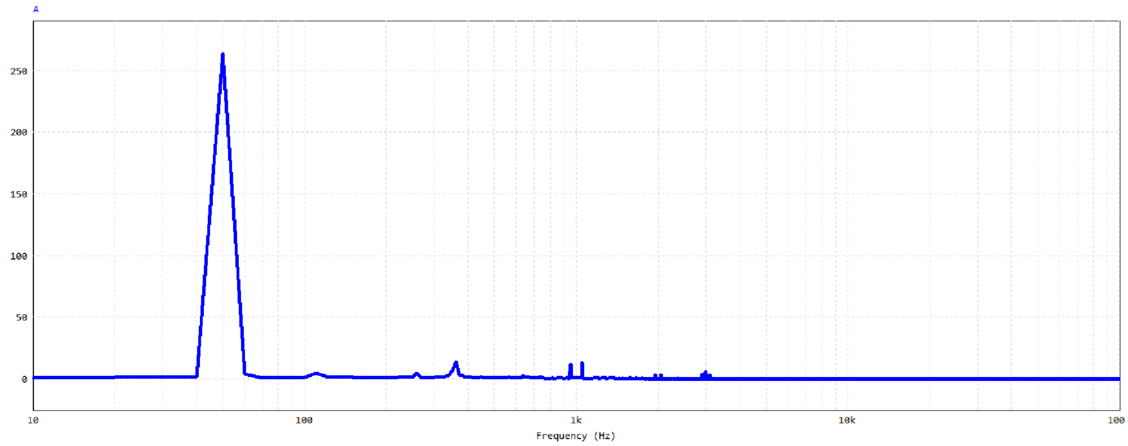

***Figure 8**. Results of modelling the output voltage spectrum of the AVI in steady-state mode*
***Source:** developed by the author*

Figure 8 clearly shows the amplitude of the main harmonic of 50 Hz and the high frequency with a switching frequency of 3 kHz and combinational harmonics consisting of sums and differences between 3 kHz and 50 Hz. The harmonic coefficient according to the simulation results was 4.9%, that is, it corresponded to the value laid down in the calculations and the given standard (DSTU IEC 62040-3:1999/COR1:2003) – 5%.

The operation of a voltage inverter under an unbalanced load as part of an electromechanical system of an autonomous WPP with ADM based on APRG is modelled. Modern standards (DSTU IEC 62040-3:1999/COR1:2003) give this requirement to a specific technical task between the developer and the customer, but according to the already invalid standard (GOST 27699-88), an autonomous wind turbine had to meet the requirements: "Effective value of the output voltage of single-phase and three-phase inverters, symmetrically loaded, should not change by more than ±10% – for three-phase inverters with a phase load asymmetry of less than 15% in the load range from 50 to 100% of the rated value." These requirements are used as a guideline. According to this requirement, the rated primary wind flow rate of 11 m/s and the rated load corresponding to 750 kW are set, and the single-phase load is increased by 15% in accordance with the standard. The graph with the simulation results is shown in Figure 9, where the amplitude value of the most loaded phase decreased from 297 V to 267 V, that is, by 10.01%, which corresponded to the value laid down in the calculation and the requirements of the standard.

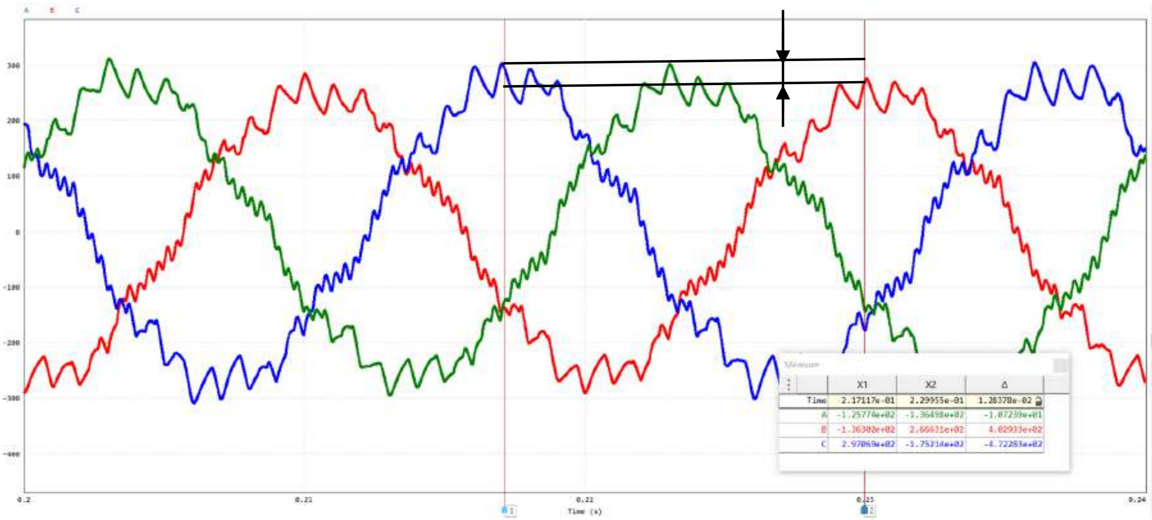

***Figure 9**. Results of modelling the shape of the output voltage of the AVI in a steady-state asymmetric mode*
***Source:** developed by the author*

The operation of a voltage inverter during load release and surge as part of an electromechanical system of an autonomous WPP with ADM based on APRG is modelled. According to the standard (GOST 27699-88), an autonomous wind turbine had to meet the requirements: "Maximum initial deviation of the output voltage for single-phase and three-phase inverters when the load current changes by a jump from zero to the nominal value and vice versa, at the rated supply voltage of inverters, should not exceed ±30% of the amplitude value of the linear or phase voltage set. The maximum deviation duration should not exceed 40 ms". That is, according to this requirement, if the rated speed of the primary wind flow is set to 11 m/s and the rated load corresponding to 750 kW, the load is reset to zero at a time of 0.31 s. The graph with the simulation results is shown in Figure 10.

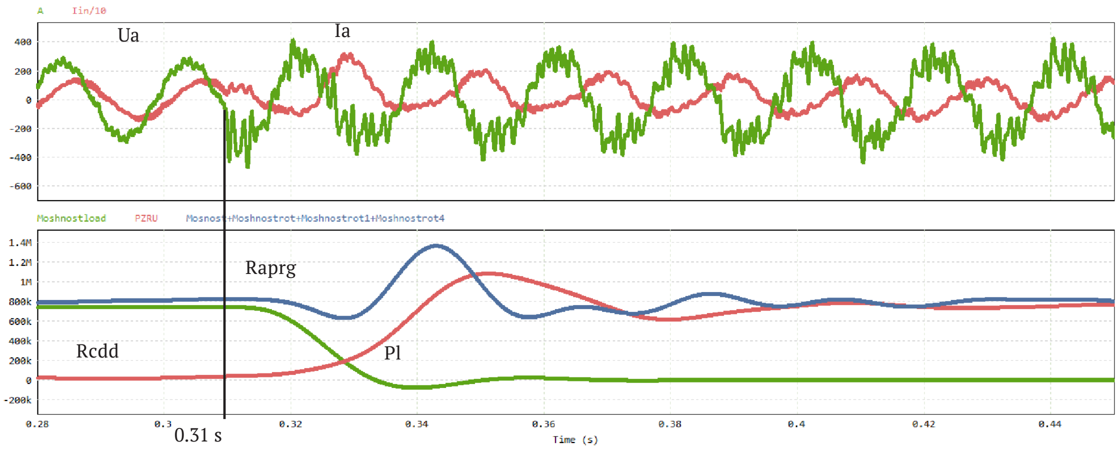

Figure 10*. Load reset simulation results*
Note: *Ua, Ia – voltage and phase current of the inverter; Raprg, Rcdd, Zl – power, respectively, of the asynchronous generator, charging and discharging device, and load*
Source: *developed by the author*

As shown in Figure 10, when the load was reset, the inverter current changed its phase, that is, the stator energy began to flow through the reverse diodes of the AVI to the DC link instead of the load. The ripple amplitude of the output voltage reached 400 V, which was 30% of the rated value. The lower graph shows how the power of the Raprg generator, the Pl load, and the Rcdd charging and discharging device were redistributed. The transition process lasted about 38 ms, and the aprg overload was almost doubled. If the nominal primary wind speed is set to 11 m/s and the load is zero, and the load is applied to the rated value of 750 kW at time 0.31 s, the reverse process can be observed. The graph with the results of modelling the load surge is shown in Figure 11.

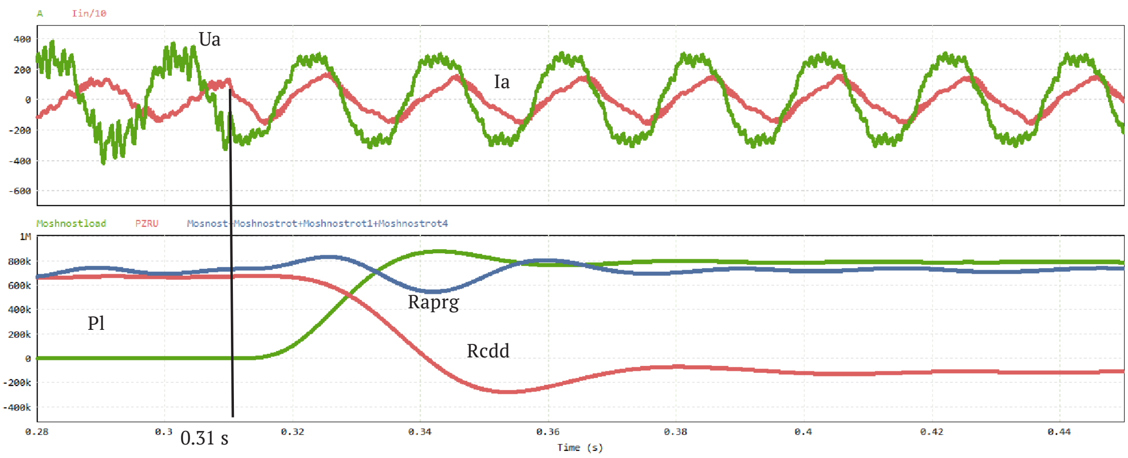

Figure 11*. Results of load surge simulation*
Note: *Ua, Ia – voltage and phase current of the inverter; Raprg, Rcdd, Zl – power, respectively, of the asynchronous generator, charging and discharging device, and load*
Source: *developed by the author*

It was possible to see that the process of the surge was more favourable for the generator, almost without overloads. Additionally, full idling in an autonomous wind turbine cannot be conditioned by the fact that the circuits of the own needs of the installation itself (power supplies of the control system, fans, alarm) are powered from the output voltage of the installation, and this gives a minimum consumption of 1 kW or more.

A significant number of studies are devoted to modelling the operation of autonomous wind turbines. P.K. Goel *et al.* (2010) started considering autonomous wind power plants based on APRG, which also uses an inverter with a zero wire, but with a vector algorithm for generating the output voltage. Their research was subsequently continued by a group of researchers led by J. Monroy-Morales *et al.* (2024), who combined the wind power plant in question with a diesel generator to increase battery life. The paper also analysed the battery life in an autonomous wind power plant. The study by M.S. Chabani *et al.* (2017) proposed a new system for direct torque control of the generator, which developed the well-known vector algorithms for controlling APRG.

The team of researchers led by S.K. Tiwari *et al.* (2018) built a model of a hybrid solar-wind power plant, which in the forecast allowed abandoning the use of a diesel generator for long periods of time without the presence of wind.

A.R. Kumhar (2018) also performed modelling of vector algorithms for regulating the generator power, but using the so-called "Transparent converter" in the APRG rotor circuit, which, on the one hand, expanded the control range, and, on the other hand, complicated the converter and reduced its efficiency.

A group of researchers led by T. Jangid *et al.* (2018) modelled a system for finding the maximum power of a wind turbine based on scanning logic, which excluded the presence of a wind flow speed sensor. A similar problem was solved by S. Puchalapalli & B. Singh (2020), who considered the use of generator power control systems based on fuzzy logic algorithms also without installing a wind speed sensor.

I.E. Atawi *et al.* (2019), V. Golovko *et al.* (2020) considered modelling of autonomous wind turbines based on synchronous permanent magnet generators and with a frequency converter at full power of a wind power plant. However, the need for complete conversion of the generated energy reduces the overall efficiency of wind turbines. M. Kovalenko *et al.* (2024) covered modelling of an autonomous wind turbine based on a synchronous generator without a frequency converter. In this case, the generator power is regulated using a magnetic gearbox, the efficiency of which remains a debatable topic.

In the proposed paper, in contrast to the ones considered, modelling covers a segment of a new type of autonomous wind turbines – with a wind turbine with aerodynamic multiplication. Simulations of these types of installations were also carried out, for example, by D.G. Alekseevskiy *et al.* (2019), but this only applied to system wind turbines. In addition, the visual-block modelling proposed by the researcher currently allowed analysing only the smooth component of voltage and currents, and the electromagnetic processes associated with the presence of switching in semiconductor wind turbine converters were ignored by the study. Without a doubt, this method of modelling has accelerated the analysis of electromechanical processes in a wind power plant, but when switching to considering electromagnetic processes in an inverter and describing its behaviour along a smooth component, a significant error will arise. The development of visual-block models that will analyse the behaviour of the inverter with its switching frequency negates the advantages of this method of analysis due to slowing down the speed of modelling, and spending time on additional development and description of models. Thus, the model in the specialised PSIM software used in this paper helped to analyse the processes in the AI with available tools with little time spent on developing a simulation model. The disadvantage of simultaneous modelling of electromechanical and electromagnetic wind turbine processes is the considerable time required for each calculation.

Conclusions

To confirm the theoretical foundations of using the developed method for calculating inverter filters for an autonomous WPP with an ADM based on an asynchronous generator with a phase rotor, a simulation model was developed using the tools of the PSIM software suite. When using the specified method of calculating the output filter of the AVI, it was possible to obtain the harmonic coefficient of the output voltage of 4.9%, which meets the requirements of the standard in force in Ukraine, which regulates the maximum value of the harmonic coefficient of the output voltage not higher than 5%. This value was included in the input data for the calculation.

The method of calculating the input filter of the inverter provided the specified requirements for the output voltage asymmetry (10%) under uneven load, when the load of one of the phases is reduced by 15% relative to the others. According to the simulation results, when setting up the regulators of the AVI control system according to the specified method, it is possible to obtain the desired quality of transients (input data for calculation: 40 ms – duration and 30% – overvoltage when the load is reset; according to the simulation results, the duration was 38 ms, and the overvoltage – 30%).

In comparison with the visual-block modelling proposed for the modelling of WPP with ADM, the simulation time of the created simulation model is higher, but the model allowed combining modelling of both electromechanical and electromagnetic processes in a wind power plant without using specially designed tools. Thus, in accordance with this goal, a full compliance of the modelling results with the input data used in the calculations can be noted.

The topic of subsequent publications will focus on modelling the energy modes of an autonomous wind power plant with an aerodynamic multiplier and analysing its behaviour at variable primary wind flow rates. When modelling changes in the primary wind flow, it is possible to exclude internal parameters of semiconductor devices from the model, for example, the dynamic resistance of IGBT and diodes, to reduce the calculation time.

Acknowledgements

None.

Conflict of Interest

None.

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Моделювання роботи інвертора напруги у складі автономної вітроенергетичної установки з аеродинамічним мультиплікуванням на базі асинхронного генератора з фазним ротором

Гліб Стрункін

Магістр
Інженерний навчально-науковий інститут Запорізького національного університету
69006, просп. Соборний, 226, м. Запоріжжя, Україна
https://orcid.org/0009-0009-1719-4132

Анотація. В умовах енергодефіциту, спричиненого знищенням енергетичної інфраструктури, нестабільністю постачання електроенергії та зростанням попиту на автономні джерела енергії, виникає потреба у розробці незалежних і ефективних систем енергозабезпечення. Особливе значення мають вітроенергетичні установки, які здатні функціонувати автономно, забезпечуючи стабільність енергопостачання навіть у кризових умовах. У зв'язку з цим актуальним є вивчення перспективних рішень, які відповідають сучасним стандартам якості та здатні інтегруватися в автономні енергетичні системи. Метою роботи було підтвердження ефективності розрахунку фільтрів інвертора у статичних та динамічних режимах, а також за умов несиметричного навантаження. Це було досягнуто на основі імітаційного моделювання автономної вітроенергетичної установки з аеродинамічним мультиплікуванням, що працює на базі асинхронного генератора з фазним ротором і збудженням від інвертора напруги. Описано імітаційну модель автономної вітроенергетичної установки, параметри інвертора, яку розраховано за авторськими методиками, у середовищі PSIM. Програмно виконано Фур'є-аналіз гармонічного складу вихідної напруги інвертора, розраховано його коефіцієнт гармонік, який не перевищує 5 %, відповідно до діючого стандарту. Доведено, що збудження від інвертора напруги поліпшує її роботу при несиметричному навантаженні та скиданні-накиданні навантаження. Виконано порівняння результатів моделювання вихідної напруги інвертора з вимогами стандартів на безперервні джерела енергоживлення. На основі результатів імітаційного моделювання автономної вітроенергетичної установки з аеродинамічним мультиплікуванням підтверджено ефективність розрахунку фільтрів інвертора напруги для асинхронного генератора з фазним ротором. Методики показали свою результативність як у статичних і динамічних режимах, так і за умов несиметричного навантаження

Ключові слова: автономний інвертор напруги; скидання та накидання навантаження; несиметричне навантаження; коефіцієнт гармонік; імітаційне моделювання