NERUBATSKYI V. P., *PhD, Associate Professor*
PLAKHTII O. A., *PhD, Associate Professor*
HORDIIENKO D. A., *Postgraduate*
Ukrainian State University of Railway Transport
Kharkiv, Ukraine

PROSPECTS FOR THE APPLICATION OF AUTONOMOUS VOLTAGE INVERTERS IN MODERN INDUSTRY AND ENERGY

Autonomous voltageinverters have the widest possibilities and areas of application. They are considered the best universal module for converting electricity. In addition to the main function of converting DC toAC, inverters can inversely perform theinverse function, ie to convert AC to DC. At zerooutput voltage, the voltageinverter is converted intoa reversible DC–DC converter. Based on it, active voltageand current filters, reactive power compensators, alternating voltage regulators, direct frequency converters are performed, ie the voltageinverter link is a sourceof new circuits.

The main areas of application of stand-aloneinverters are [1, 2]:

– power supply of AC consumers in devices in which oneof theenergy sources is a rechargeable battery (onboard secondary power sources, backup household power supplies, etc.), as well as backup power of responsible consumers in caseof possible disconnection of theAC network;

– electric vehicles powered by the catenary or any sourceof direct current, in which as traction motors it is desirable to have simple, reliableand cheap short-circuited induction motors;

– electric drive with asynchronous and synchronous motors, in which the circuit of theautonomous inverter serves as a sourceof regulated voltageand frequency;

– devices for obtaining alternating current of the required frequency from sources of direct energy conversion (thermo- and photoelectric generators, fuel cells), which produceenergy on direct current;

– electrothermia toobtain high frequency alternating current (metal melting, heating and hardening of products).

Depending on the typeof medium frequency power supply system, the requirements for stand-aloneinverters can differ significantly and havea significant impact on the choiceof circuit solution, control and protection principles, methods of regulating operating modes [3, 4].

The basis of a stand-aloneinverter is a valve switching device that can be performed on single-phaseand three-phase circuits (circuits with zerooutput or bridge circuits). Transistors and thyristors are used as switches in inverters. When using single-operation thyristors, the circuit is supplemented with elements designed for their switching. Oneof the main elements is a capacitor. It is important to note that the purposeof capacitors is not limited to the closureof thyristors. Capacitors arealso used to form theoutput voltage curveof theinverter, to determine the natureof the transients in theAC circuit and toincrease the voltageon the load [5, 6].

Single-phaseautonomous voltageinvertersis most often performed according to the bridge scheme (Fig. 1). The load (usually active-inductive) is included in the diagonal of the bridge formed by thyristors *VS1–VS4*and back-connected diodes *VD1–VD4*. Diodes are designed to pass the current of active-inductive load in timeintervals when the current has theopposite direction for thyristors (diodes reverse, counter, or "reactive" current).

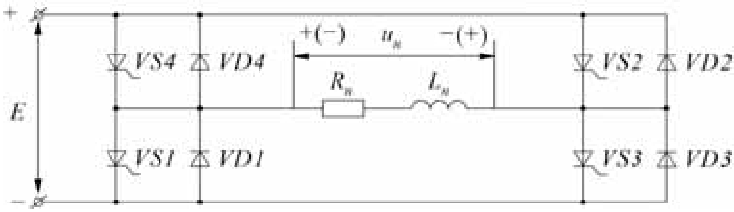

Fig. 1. Schemeof power circuits of single-phaseautonomous voltageinverter

The formation of theoutput voltage curveis characterized by processes occurring in the main circuits of theinverter (with thyristors *VS1–VS4*, diodes *VD1–VD4*and load) when setting theappropriate conduction intervals of thyristors.

Autonomous voltageinverter, as a converter of a constant input voltageintoan alternating output voltage, receives power from a voltage sourceof non-inductive nature. Theinput current of theinverter will be pulsed (with a current jump), which does not allow the presencein theinput sourceof inductance. Real input voltage sources (usually rectifiers) usually haveinductance. Toeliminateits influence, theinput of the voltageinverter includes a filter capacitor of sufficient capacity, which is the first featureof the voltageinverter. The second featureof the voltageinverter is that theinput current can take negative values at a large phase shift of theoutput current of theinverter relative to theoutput voltage. This requires the presenceof two-way conductivity in theswitchesof theinverter valve kit, ie theswitches must be shunted by reverse current valves.

Widely used is a dependent inverter that operates in the presencein its output circuit of an AC voltage source, which specifies the shape, frequency and magnitudeof the voltageof theAC voltage network formed by it. AC consumers can bein this network, and the task of the dependent (from this network) inverter is to supply it with additional active power. An exampleof the useof a dependent inverter can beobserved in a DC power transmission system when twoAC power systems are connected. In this case, at the transmitting end of the line, the rectifier converts alternating voltageinto direct current, and at the receiving end – the dependent inverter converts direct current intoalternating current, adding its activeenergy to the power system. It is possible to change the functions of the valve transducers to reverse to reverse the flow of active power in the DC line.

Known topologies of autonomous voltageinverters, which are used in power supply systems using alternativeenergy sources, can be divided into single-level and multi-level circuit variations [7]. In turn, multilevel topologies can be classified according to the circuitry of the power part of a separate module (cell) –a module using theimpedanceand quasi-impedance link in theinput circuit of the converter. A featureof such inverters is theability to work in an additional mode, the so-called "breakdown mode". This allows toincrease theinput current and voltageof theinverter and allows to transfer maximum power from an alternative voltage source (solar panel, wind turbine, biofuel cell) to the load.

Modern converter control algorithms are pulse width modulation (PWM) and single modulation. It should be noted that different modulation systems cause quite different sinusoidal indices of output voltageand current and different ripple coefficient of input current [8].

When building power supply systems with renewableenergy sources as a sourceof direct current, converters with an impedance link in theinput circuit deserve special attention. This typeof inverter is a two-level voltage converter with a DC circuit at theinput, consisting of a connected *x*-configuration of two capacitors and chokes. In Fig. 2 shows a block diagram of az-inverter.

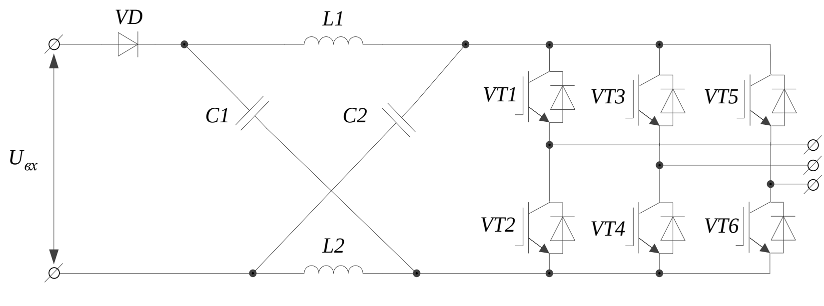

Fig. 2. Block diagram of thez-inverter

The link of energy storage consists of two series-connected inductors (*L1* and *L2*) and two parallel capacitors (*C1* and *C2*). A diode rectifier, a solarpanel or a fuelcellcanbe used as a DCpowersource. This topology includes six semiconductor powers witches (IGBT or MOSFET). The peculiarity of such a converter is that the impedance link allowsto use the mode of operation ofpowerswitches – the mode of "breakdown".

The advantage of this mode isto increase the inputcurrent and voltage of the inverter, which istakenfromthe DCsource without installing additionalconverters atthe input ofthe circuit. It allowsto transferthe maximumpower ofthe solarpanelto the load, which, inturn, allowsto rationallyuse the area ofthe solarpanel.

References

1. Shav′olkin O. O., Nalyvayko O. M. Peretvoryuval′na tekhnika: Navch. posibnyk. Kramators′k: DDMA, 2008. 328 s.

2. Mali S. M., Patil Dr. B. THD Minimization in Multilevel Inverter Using Optimization Approach. *International Journal of Engineering Research & Technology (IJERT)*. 2018. Vol. 7, Issue 6. P. 97–100.

3. Nerubatskyi V. P., Plakhtiy O. A., Kavun V. E., Mashura A. V., Hordiienko D. A., Tsybulnyk V. R.Analysis of indices of energy efficiency of autonomous voltage inverters with various modulation types. *Collection of scientific works of the Ukrainian State University of Railway Transport*. 2018. Issue 180. P. 106–120.

4. Malinowski M., Gopakumar K., Rodriguez J., Perez M. A. A survey on cascaded multilevel inverters. *IEEE Trans. Ind. Electron*. 2010. Vol. 57. P. 2197–2206.

5. Bai Z., Zhang Z. Conformation of multilevel current source converter topologies using the duality principle. *IEEE Trans. Power Electron*. 2008. Vol. 23. P. 2260–2267.

6. Plakhtii O. A., Nerubatskyi V. P., Hordiienko D. A., Tsybulnyk V. R. Analysis of the energy efficiency of a two-level voltage source inverter in the overmodulation mode. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*. 2019. No. 4 (172). P. 68–72. DOI: 10.29202/nvngu/2019-4/9.

7. Borrega M., Marroyo L., Gonzalez R., Balda J., Agorreta J. Modeling and control of a master-slave PV inverter with n-paralleled inverters and three-phase three-limb inductors. *IEEE Trans. Power Electron*. 2013. Vol. 28. No. 6. P. 2842–2855.

8. Plakhtii O., Nerubatskyi V., Sushko D., Hordiienko D., Khoruzhevskyi H. Improving the harmonic composition of output voltage in multilevel inverters under

an optimum mode of amplitude modulation**.** *Eastern-European Journal of Enterprise Technologies*. 2020. Vol. 2, No. 8 (104). P. 17–**2**4. DOI: 10.15587/1729-4061.2020.200021.

ПАНЧЕНКО В.В., *к.т.н., доцент*
МАСЛІЙ А. С., *к.т.н., доцент*
Український державний університет залізничного транспорту
Харків, Україна

ОГЛЯД СТАНУ ЕЛЕКТРОФІКАЦІЇ ЗАЛІЗНИЦЬ УКРАЇНИ ПОСТІЙНИМ ТА ЗМІННИМ СТРУМОМ

Згідно з інформацією, розміщеною на сайті Міністерства інфраструктури України, в нашій країні зараз електрифіковано 9926 кілометрів залізниць. Загальна протяжність залізниць України на даний момент (без урахування окупованих територій Криму і Донбасу) складає 19790 кілометрів. Таким чином, в нашій країні електрифіковано майже половина всіх залізничних ліній Це дуже хороший показник – по ньому ми знаходимося на рівні більшості європейських країн.

Головною перевагою електричної тяги на залізницях є те, що вона набагато дешевше, ніж тепловозна. Різниця становить, як мінімум, півтора-два рази, що залежить від вартості палива в конкретній країні, а також технічного рівня парку тепловозів. Електровози, як правило, розвивають значно більшу швидкість, ніж тепловози, тому всі швидкісні і високошвидкісні залізниці світу електрифіковані. Крім того, електровози можуть вести більш важкі поїзди і простіше в технічному обслуговуванні, ніж тепловози. Середньостатистичний електровоз значно потужніше середньостатистичного тепловоза – потужність сучасних електровозів складає від 4475 до 7350 кВт., а тепловозів – від 2940 до 4475 кВт.

Хоча на початку цього століття в світі було електрифіковано лише близько 25 % залізниць (за даними роботи професора А.В. Котельникова «Електрифікація залізниць»), по електрифікованих залізницях перевозилося більше 50 % всіх вантажів, що відправляються залізничним транспортом в світі. В Україні зараз за допомогою електричної тяги перевозиться близько 80% всіх вантажів.

З іншого боку, електрифікація потребує досить значних фінансових інвестицій - електрифікацію одного кілометра залізниці в Європі оцінюють в 2 - 3 мільйони доларів США (в залежності від роду струму і напруги).