



IMPLEMENTATION OF MULTILEVEL POWER INVERTER

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ABSTRACT

This article proposes one of the methods for multilevel power inverter implementation with capacity up to 30 kW. This method is based on a special topology for construction of multilevel inverter consisting of H-bridge and level switch. In accordance with the proposed topology H-bridge inverts voltage and a switch enables to get any number of voltage levels. In addition, the characteristic feature of this inverter is the use of converters as sources where multilevel voltage is generated. This allows reducing a number of accumulator batteries being used, decrease the dependence of the form of the inverter output voltage from the accumulators charging rate, as well as the dimensions of the whole unit. 17-level inverter has been developed following the proposed topology and methodology. The article highlights the results of simulation in MATLAB and an experimental inverter unit.

Keywords: multilevel inverter, implementation, topology, switching angles, THD.

INTRODUCTION

Following the development of alternative sources of energy the development of multilevel inverters is becoming more essential. There are many different methods for multilevel inverter construction. Most of them are described in details in [1,2]. The most common schemes of multilevel inverter implementation are the varieties of «cascaded H-bridge» [3,4], as well as diode clamped inverters [5,6] or inverters with flying capacitors [7]. These works mainly focused on reducing the number of power keys used and inverter output voltage appropriate at the level of harmonic components. In this case the details of multilevel inverter construction are not considered. Too little attention is paid to the methods of voltage generation equal to 312 V, and in some cases [8] even higher.

As the autonomous inverter is practically used with wind and the Solar energy conversion system, the role of electric energy accumulators is played by accumulator batteries. Usually [9,10] these are lead-acid batteries with voltage of 12 or 24 V. Consequently to generate voltage of 312 V, we need 26 accumulators with voltage of 12 V or 13 accumulators with voltage of 24 V. In such a manner the whole energy conversion system will occupy a large area and be unfit for transportation. Furthermore, because of the frequent cycles of charge-discharge even using special charging algorithms, the life of accumulator batteries will be significantly reduced [11]. In addition, real voltage of accumulator batteries will differ from the nominal at least ± 2 V depending on the state of their charge. This will have pernicious influence on half-period average output voltage of the inverter.

This article proposes a technical solution which allows reducing a number of accumulator batteries being used as well as multilevel inverter implementation combining H-bridge and level switch. In addition to the above, a level switch allows forming any number of voltage levels at the inverter output.

PROPOSED INVERTER TOPOLOGY

The proposed topology is shown in the Figure-1. Multilevel inverter consists of H-bridge and level switch. Multilevel inverter voltage is generated by way of consecutive switching the power keys T1-T8 on and off according to a certain law which in such a manner commutate converters voltage. As voltage converters have a fixed value of output voltage to generate 8 voltage levels, it is proposed to use 5 converters with output voltage of 48 V and 3 converters with voltage equal to 24 V.

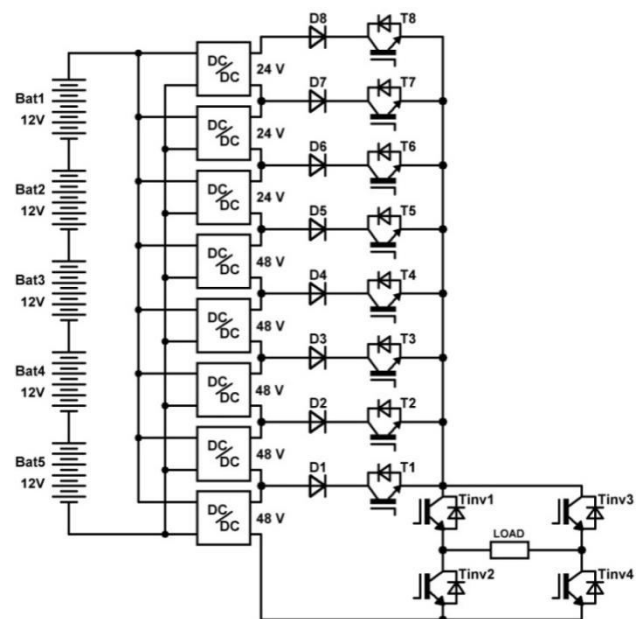


Figure-1. Proposed topology for multilevel inverter.

The power source is represented by 5 accumulator batteries with voltage of 12 V. Batteries may be charged from solar panel or wind power generator correspondingly. If SD-1000L-48 and SD-1000L-24 convertors produced by MeanWell Company, are used instead of a voltage convertor, so from 2 to 6



consecutively connected accumulator batteries with voltage of 12 V can be used for the power needs, as the input of such convertors can accept voltage from 19 to 72 V.

Attention should be paid to how accumulator batteries are connected. As MeanWell SD-1000L converters have galvanic isolation between the output and input, it is possible to connect all convertors to accumulator batteries simultaneously. An ideal alternative is the use of 5 accumulator batteries, because a bigger number can cause overheating of convertors, a smaller number will decrease output power or the whole unit.

SIMULATION

The basic factor which a coefficient of harmonic component directly depends on in output power of multilevel inverter is choosing the switching time for voltage levels. There are many ways to determine the switching time for voltage levels of inverter. Methods based on Shifting PWM [1,12,13] are used more often. All of them are focused on making the level output voltage of the inverter more sinusoidal and reducing its harmonic components. However, these methods don't comprise the fact that such parameters of the inverter output voltage as

frequency, amplitude and effective value should comply with the parameters of industrial voltage. We have used a method described in [14] for the inverter being developed where to find switching time of a certain voltage level we should use the following formula

$$t_c = \frac{U_h \sin^{-1} \frac{U_h}{A} - U_l \sin^{-1} \frac{U_l}{A} + A \cos(\sin^{-1} \frac{U_h}{A}) - A \cos(\sin^{-1} \frac{U_l}{A})}{2\pi f(U_h - U_l)}.$$

In this expression A is an amplitude of sinusoidal voltage, U_h – amplitude of upper level, U_l – amplitude of lower level, f – frequency.

In accordance with this formula we make a practical calculation for a 17-level inverter. Since the voltage will be produced by eight convertors of 24 V or 48 V connected consecutively, having considered the steepness of sinusoidal voltage, they should be placed so as they could create voltage levels 48, 96, 144, 192, 240, 264, 288 and 312 V correspondingly. The obtained data are summarized in the Table-1. There are data for the positive half-wave of the voltage only in this table. To form a negative half-wave, the values need to be moved to 0.01 sec or 180°.

Table-1. Switching angles in 17-level inverter.

Level	Voltage, V	Switching time, s	Switching angles, deg
1	48	0.25·10 ⁻³ - 9.75·10 ⁻³	4.41° – 175.59°
2	96	0.74·10 ⁻³ - 9.26·10 ⁻³	13.35° – 166.65°
3	144	1.3·10 ⁻³ - 8.7·10 ⁻³	23.4° – 156.6°
4	192	1.8·10 ⁻³ - 8.2·10 ⁻³	32.4° – 147.6°
5	240	2.4·10 ⁻³ - 7.6·10 ⁻³	43.2° – 136.8°
6	264	3.0·10 ⁻³ - 7.0·10 ⁻³	54° – 126°
7	288	3.5·10 ⁻³ - 6.5·10 ⁻³	63° – 117°
8	312	4.2·10 ⁻³ - 5.8·10 ⁻³	75.6° – 104.4°



A 17-level inverter has been simulated based on the obtained results in MATLAB Simulink software environment (Figure-2). The result of simulation is generation of step voltage at the inverter output (Figure-3). When amplitude is 311 V, the mean square value is 220.5 V.

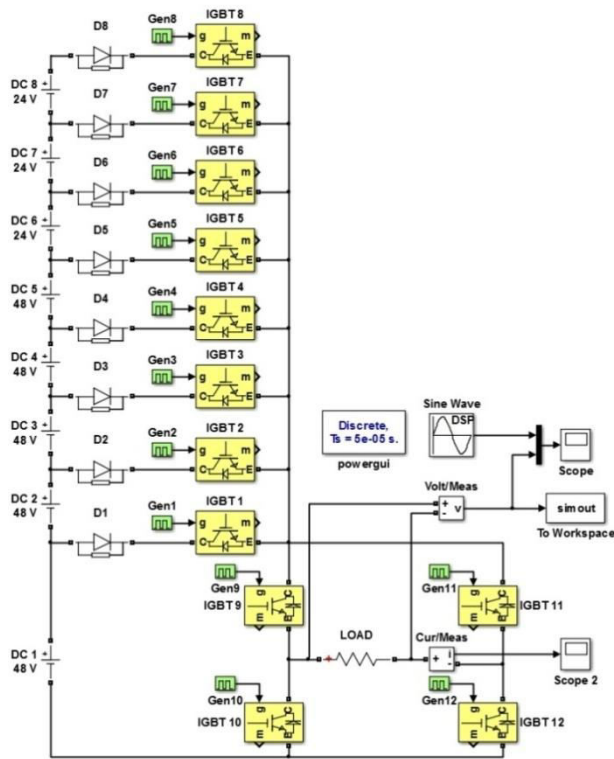


Figure-2. 17-level inverter model.

The parameters of inverter output voltage and its harmonic composition were studied with the help of powergui block (Figure-4). The ratio of harmonic distortion is 4.73% only which a good result is in comparison with [15]. It should be noted that in this case relative to others 33 and 37 of harmonic are delivered. They can be easily eliminated using LC-filter.

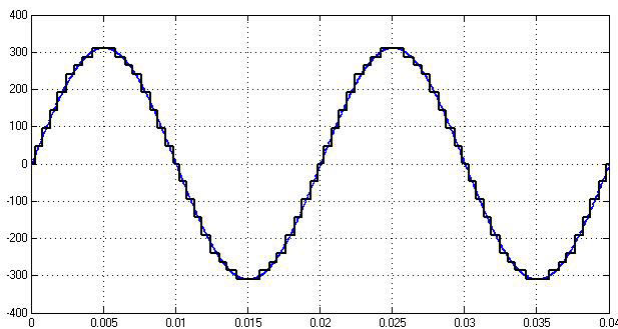


Figure-3. Result of modeling in MATLAB Simulink: form of output voltage of 17-level inverter.

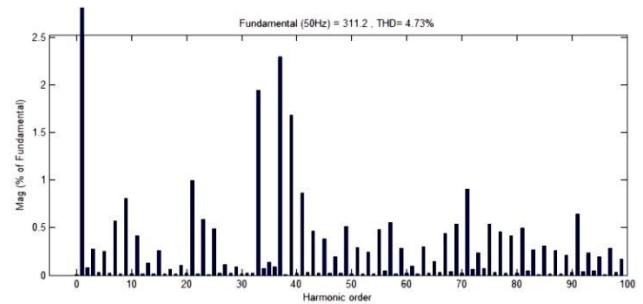


Figure-4. Result of modeling in MATLAB Simulink: FFT of output voltage of 17-level inverter.

EXPERIMENTAL RESULTS

After validating the scheme in MATLAB environment, an experimental unit has been assembled. The Figure-5 shows a structural scheme of inverter and Figure-6 and Figure-7 - an experimental unit. The inverter consists of 8-channel switch, H-bridge and control system based on ATmega32A microcontroller.

H-bridges made on the basis of intellectual power module Mitsubishi PM75CLA120. It consists of control impulse amplifier and protection scheme against short circuit, current overload, and low power voltage or module high temperature. 8-channel level switch is assembled based on IGBT G7PH42UD of International Rectifier. To provide galvanic isolation between control and power circuits we should use a quick-acting solid relay HCPL-4503. Nominal power of the developed 17-level inverter - 30 kW.

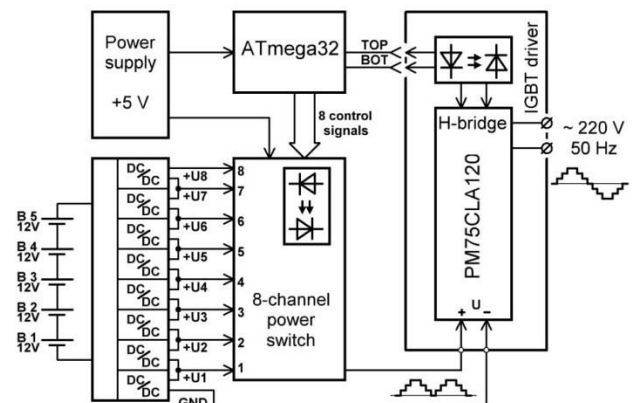


Figure-5. Block diagram of the experimental unit.

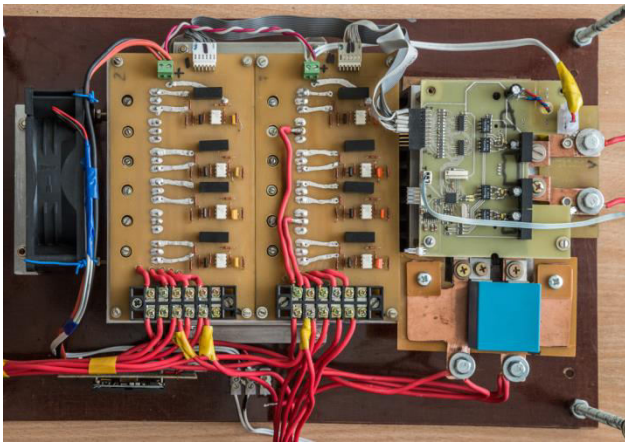


Figure-6. Photograph of the level switch scheme and control system.

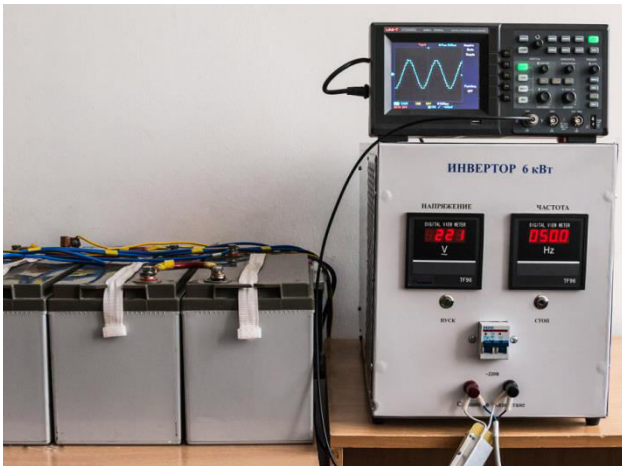


Figure-7. Photograph of the experimental unit.

Figure-8 shows an oscillogram of sinusoid shaped output voltage of the inverter for active load constructed according to the switching angles in Table-1. As it can be noted, the form of multilevel inverter output voltage is more sinusoidal.

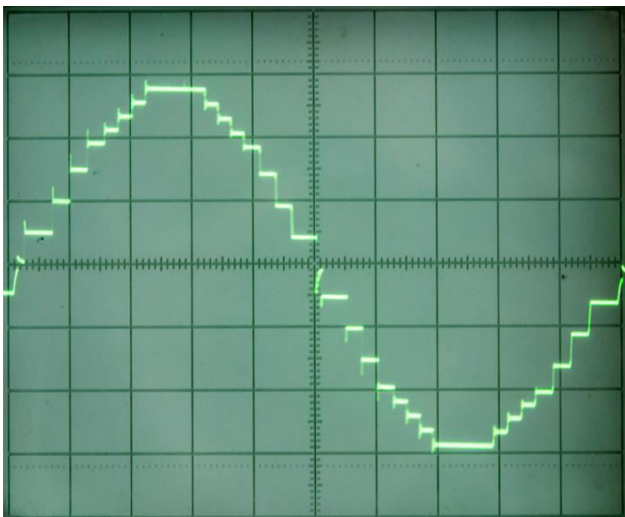


Figure-8. Output voltage of 17-level voltage inverter.

CONCLUSIONS

This article has proposed implementation of multilevel power inverter where voltages from convertors are consecutively commutated and inverted using the scheme of H-bridge. Also there was proposed an alternative topology for multilevel inverter construction. This topology may be used to generate voltage of any number of levels. In accordance with the proposed topology, the 17-level inverter, ideal in respect of the harmonic distortions and price, has been developed. Only 5 accumulator batteries have been used as a source of constant voltage of the inverter. This allowed reducing dimensional indicators of the whole system greatly. The article highlights a scheme of construction, results of simulation in MATLAB software environment and experimental unit of the inverter with capacity up to 30 kW.

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