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Conference paper 446-22

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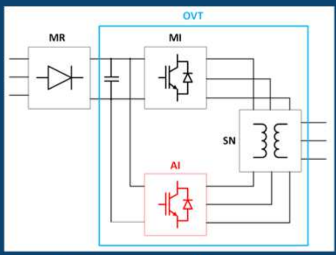
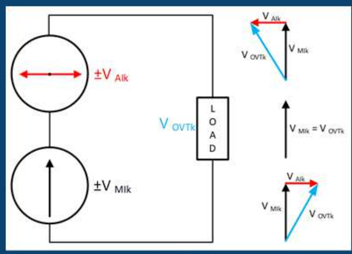
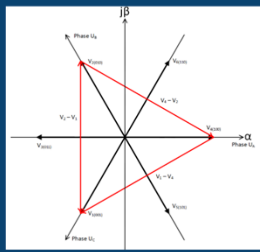
The active filtering of the inverter output voltage by use of orthogonal vectors' control strategy

The paper proposes a creative control method permitting to filter output voltage waveforms of the inverter. The main idea is based on the assumption that the total inverter output space vector is carefully chosen as a composition of two space vectors generated by 2 two-level inverters. The total built-up inverter is assembled of two standard three-phase inverters: a main inverter (MI) and an auxiliary one (AI) serving as an active filter. The output voltage space vector of the built-up inverter is composed of one or two space vectors generated by the respective inverters. The space vectors of the auxiliary inverter are orthogonal to the respective space vectors of the main inverter. The structure and its performance as well as the control method using specified vectors are discussed in the paper.







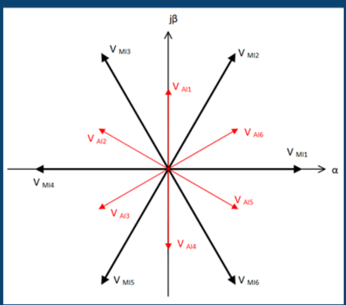
$\underrightarrow{V}_{MIk}$ – the voltage vector of the main inverter, $\underrightarrow{V}_{AIk}$ – the voltage vector of auxiliary inverter, $\underrightarrow{V}_{OVTk}$ – the voltage vector of the output OVT inverter

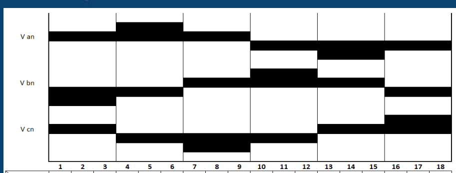
$$\begin{cases} \underrightarrow{V}_{Ok-} = (1 - jm)\ \underrightarrow{V}_{Mk} = \sqrt{1+m^2}\ \underrightarrow{V}_{M} \\ \underrightarrow{V}_{Ok} = \underrightarrow{V}_{Mk} = \left| \underrightarrow{V}_{Mk} \right| e^{j\left[(k-1)\frac{\pi}{3} \pm 2k\pi\right.} \\ \underrightarrow{V}_{Ok+} = (1 + jm)\ \underrightarrow{V}_{Mk} = \sqrt{1+m^2}\ \underrightarrow{V}_{M} \end{cases}$$

$$\begin{cases} \underrightarrow{V}_{Mk} = \left| \underrightarrow{V}_{Mk} \right| e^{j\left[(k-1)\frac{\pi}{3} \pm 2\pi n\right]} \\ \underrightarrow{V}_{Ak} = \pm jm\, \underrightarrow{V}_{Mk} = \pm m\, \underrightarrow{V}_{Mk}\, e^{j\frac{\pi}{2}} \end{cases}$$

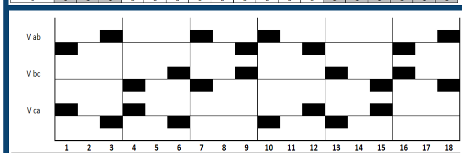
The symbol k⊕3 denotes the sum modulo 6 of the index k and the number 3.

$$\underrightarrow{V}_{Ok-} = \underrightarrow{V}_{Ak \oplus 3} + \underrightarrow{V}_{M}$$
$$\underrightarrow{V}_{Ok} = \underrightarrow{V}_{Mk}$$
$$\underrightarrow{V}_{Ok+} = \underrightarrow{V}_{Ak} + \underrightarrow{V}_{Mk}$$

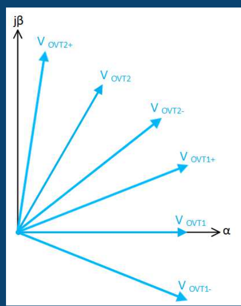




vectors / phases	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
vectors	v5	v5	v5	v4	v4	v4	v6	v6	v6	v2	v2	v2	v3	v3	v3	v1	v1	v1
a	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
b	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
c	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1



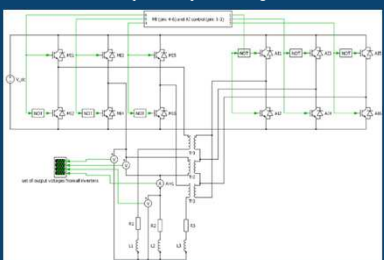
vectors / phases	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
vectors	v3	v7	v4	v1	v0	v6	v5	v7	v2	v4	v0	v3	v6	v0	v1	v2	v0	v5
a	0	1	1	0	0	1	1	1	0	1	0	0	1	1	0	0	0	1
b	1	1	0	0	0	1	0	1	1	0	0	1	1	1	0	1	0	0
c	1	1	0	1	0	0	1	1	0	0	0	1	0	1	1	0	0	1



$$m = \frac{\left|\underrightarrow{V}_{Ak}\right|}{\left|\underrightarrow{V}_{Mk}\right|} = tg\left(\frac{\pi}{9}\right) = 0{,}364$$

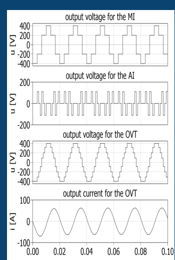
Simulation experiment

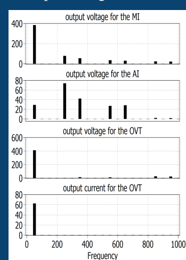
Simulation studies were performed using PLECS software. The model of the orthogonal inverter equipped in the adder system in the form of transformer is shown in figure. The primary transformer windings are delta-connected to the AI auxiliary inverter output while the secondary windings are connected in series with the load of the main inverter. Thus the AI phase-to-phase voltage is transformed to the respectively selected auxiliary voltage which is connected in series with the output voltage of the MI.



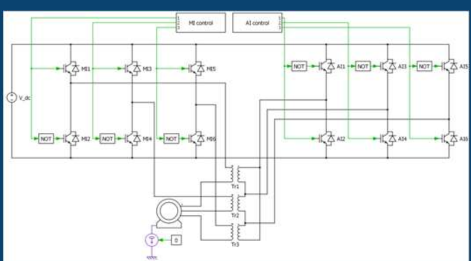
List of selected parameters of output voltage and currents for MI and OVT

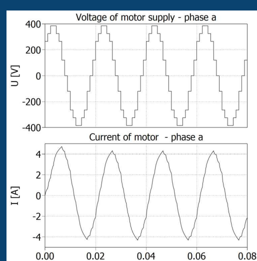
	R = 2 Ω, L = 20 mH	R = 50 Ω, L = 20 mH
u_{MI_RMS} [V]	282.8	282.8
$THD_{MI\text{-}u}$ [%]	31.1	31.1
u_{OVT_RMS} [V]	298.9	298.9
$THD_{OVT\text{-}u}$ [%]	10.6	10.6
i_{OVT_RMS} [V]	44.0	5.77
THD_{OVT_i} [%]	0.7	2.1





The output voltages waveforms: main inverter (MI), auxiliary inverter (AI), orthogonal inverter (OVT) and orthogonal inverter output current (OVT) and their spectra at R = 2 Ω, L = 20 mH.





Waveforms of voltages and currents for a load in the form of an induction motor.

List of output voltage parameters for the auxiliary and orthogonal inverter with different transformer winding ratios

$N_{MI}:N_{AI}$	$u_{AI\_}$ RMS [V]	$u_{AI\_}$ THD [%]	$u_{OVT\_}$ RMS [V]	$u_{OVT\_}$ THD [%]
45:100	181.8	345	336.2	31.6
33:100	133.3	345	312.7	19.1
26:100	105.2	345	301.8	12.8
22:100	86.9	345	298.9	10.6
18:100	74.1	345	292.3	10.8
16:100	64.5	345	290.1	12.1
14:100	57.1	345	288.5	13.4
12:100	51.3	245	287.4	14.8

where: N_{MI} - number of transformer windings on the main inverter side, N_{AI} - number of transformer windings on the auxiliary inverter side

Conclusions

The orthogonal vectors theory presents a very useful tool to design control strategy of the OVT inverter built from two standard three phase inverters. Such a solution is particularly suitable to produce a stepped output voltage characteristic to multilevel inverters. Thanks to the presented control method, the harmonic content of the output voltage is reduced. The THDU factor reaches lower values thanks to filtering properties of the OVT inverter and output voltage waveforms are better similar to sine-waves. The power of the auxiliary inverter AI is significantly reduced in relation to thr main inverter MI. The switching frequency of both inverters is very low, so the power losses of the OVT inverter is maximally limited. The inverter in question seems to be a significant alternative to recently developed numerous multilevel inverters. Moreover, the idea of the OVT inverter has the property of recurrence.