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Two phase systems, half bridge converters, LLC converter, direct matrix converters, split-single phase induction motor, torque-speed characteristic

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NEW CONCEPT OF 2-PHASE ELECTRONIC DRIVE SYSTEM FOR HOME-, INDUSTRIAL AND TRANSPORT APPLICATIONS

The paper deals with power electronic two-phase orthogonal system for home-, industrial- and transport drives applications with IM/PMSM motors. It consists of two-stage converter comprises: resonant LLC converter with AC output, two-phase matrix converter commutated by HF AC input voltage, and two-phase induction/synchronous motors. The proposed system with AC interlink, in comparison with currently used conventional systems. As a consequence of that the advantage is then less number of semiconductor devices. Such a configuration features a good efficiency of electronic converters (due to soft switching of both converters) and also good torque-speed characteristics of two-phase AC motors. Results of simulation compared to experimental verification carried-out ones are given in the paper.

NOWY KONCEPT DWUFAZOWEGO PRZETWORNIKA MOCY w NAPEDACH ELEKTRYCZNYCH DLA ZASTOSOVAŃ PRZEMYSLOWYCH I TRANSPORTOWYCH

Artykuł dotyczy zastosowania dwufazowego przekształtnika mocy w napędach z silnikiem indukcyjnym lub silnikiem synchronicznym z magnesami trwałymi (z ang. IM/PMSM) dla urządzeń domowych, przemysłowych i transportowych. System ten składa się z: przetwornika rezonansowego LLC z wyjściem AC, dwufazowego przetwornika matrycowego komutowanego napięciem wejściowym AC o wysokiej częstotliwości i z dwufazowego silnika indukcyjnego/ synchronicznego. Proponowany system cechuje się mniejszą ilością urządzeń półprzewodnikowych, większą sprawnością przetworników mocy oraz dobrą charakterystyką mechaniczną dwufazowych silników prądu zmiennego w porównaniu z konwencjonalnymi systemami. Wyniki z symulacji oraz ich weryfikacja na podstawie wyników z laboratorium będą przedstawione w tym artykule.

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1. BASIC PRINCIPLE OF TWO-PHASE MOTOR DRIVING SYSTEM

Basic principle of two-phase motor driving system is depicted in Fig. 1 [1]. It usually consist of DC-source (e.g. accu-battery), DC interlink with filter capacitor, two-phase voltage VSI inverter, and 2-phase AC motor.

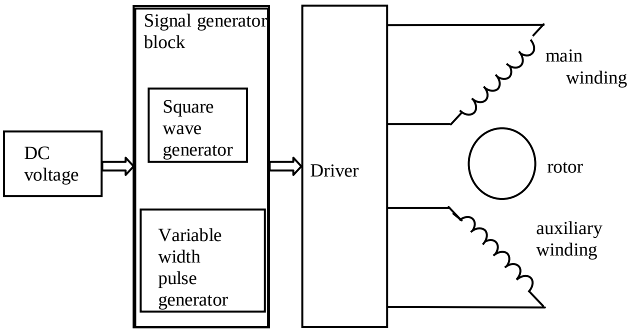
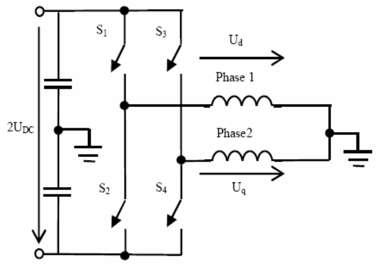


Fig. 1 A simplified diagram of a two-phase power electronic drive system [1]

a)



b)

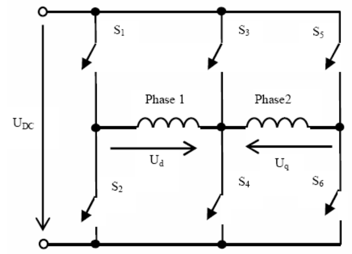


Fig. 2 Principle circuit diagrams of two-phase inverters with VSI inverter [5], [6]

Such a system (Fig. 2a,b) are rather simply, however it has several drawbacks [13], one of them is that input DC voltage must be matched with motor terminal voltage, and it can be problem for EV application.

2. NEW TWO-STAGE ELECTRONIC DRIVE SYSTEM WITH AC INTERLINK

Block scheme and circuit diagram of single branch are shown in Fig. 3a,b.

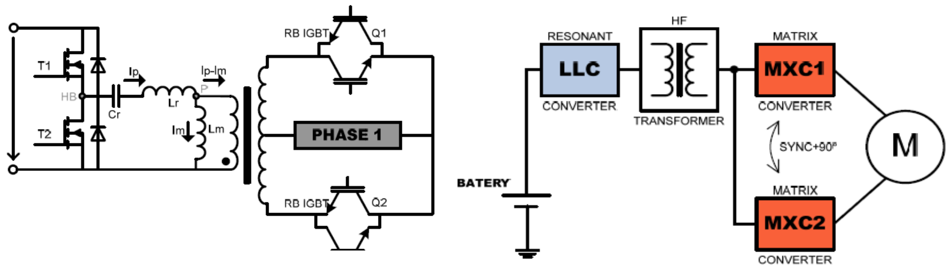


Fig. 3a,b Block scheme and circuit diagram of single branch with LLC- and HB matrix converters

Operation of 1-stage LLC converter is done [7], [8]; important is that converter operates at zero-voltage-switching (ZVS) mode with consequently minimal switching losses.

Substituted circuit diagram of half-bridge single-phase matrix converter is depicted in Fig. 4. Theoretical analysis of single-phase matrix converter has been done, e.g. [10], [11], [25]. As mentioned matrix converters work in half-bridge connection (see next Fig. 6) and ge-nerate bipolar PWM (2-20 kHz) modulated output voltages for each phase of 2-phase IM [9], Fig. 5.

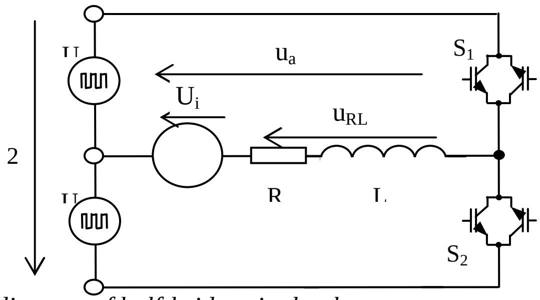


Fig. 4 Substituted circuit diagram of half-bridge single-phase matrix converter as 2nd stage

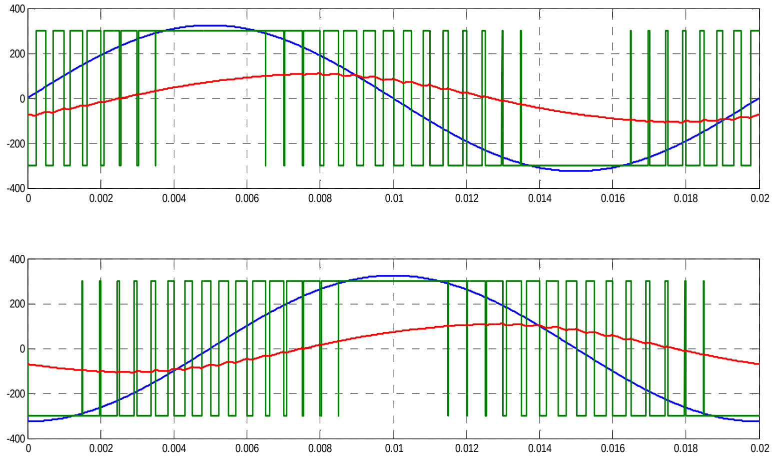


Fig. 5 Output voltages of matrix converters with bipolar PWM (5 kHz) and partial over-modulation (5 %) under R-L load

3. TWO-PHASE AC IM CHARACTERISTICS WORKED-OUT ON TEST RIG

Investigated split-single phase induction motor [17], [18] has been supplied by two half-bridge matrix converters (Fig. 6) and loaded by dynamometer on the test rig. The output quantities of the matrix converters, i.e. their output voltages and currents, are presented in Fig. 7.

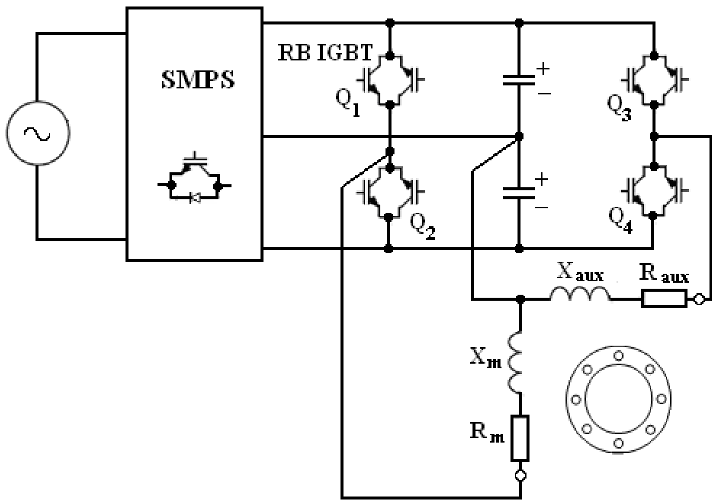


Fig. 6 Connection diagram of matrix converters and investigated IM on test rig

The voltages are in good accordance with predicted ones in Fig. 5. The currents are not exactly sinusoidal due to slightly different parameters of the main and auxiliary phases of IM and voltage over-modulation. Anyway they are very similar to those of presented in [5], [6].

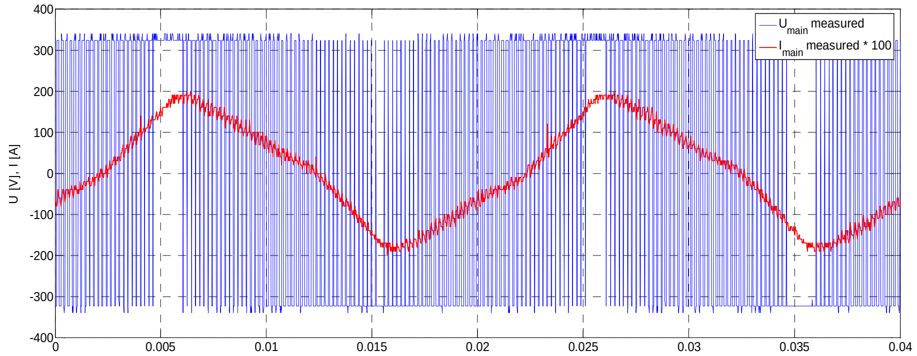


Fig. 7 Measured output voltages (switched waveform) and currents of the two-phase matrix converter under motoring load

The whole test rig system has been controlled by Freescale DSP 56F8013DEMO. Worked-out results for toque-speed characteristic are given in Fig. 8 and compared with simulated ones.

As can be seen from the Fig. 8 powering IM by power supply gives roughly results as predicted by various calculation methods.

Parameters of the investigated motor and the simulation ones are given in appendix.

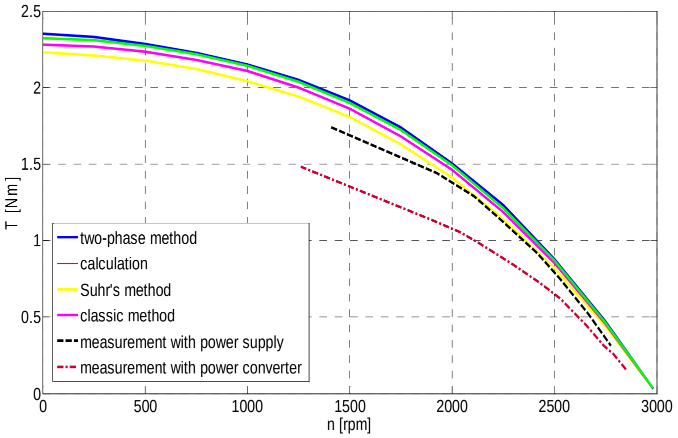


Fig. 8 Measured and predicted torque-speed characteristics under different powering of IM

4. NEW CONCEPT OF ELECTRONIC DRIVE FOR EV AND OTHER APPLICATIONS

Based on configuration in Fig. 3a,b is possible to design concept of electronic propulsion system for 2/ or 4 driven wheels, Fig. 9.

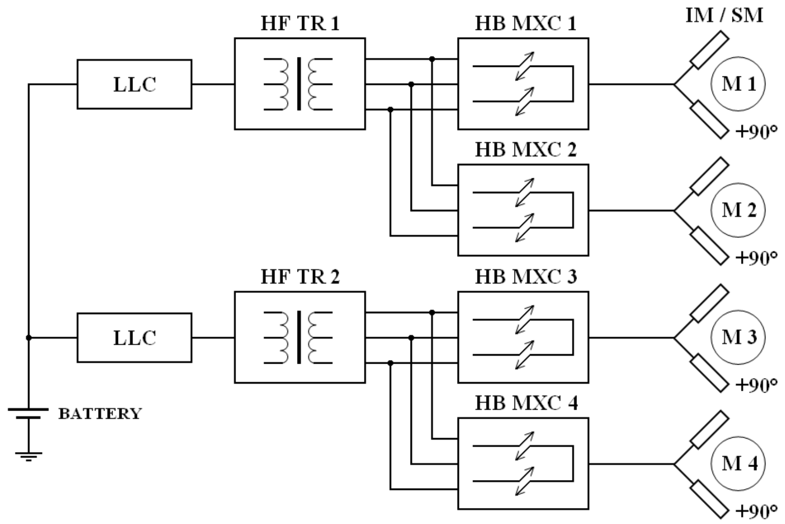


Fig. 9 Propulsion system concept for 2/4 wheels EV with half-bridge matrix converters and 2-phase induction motors

5. CONCLUSIONS

There is shown a new concept of electric propulsion system for electric vehicle consist of resonant LLC converter with AC output, two-phase matrix converter commutated by HF AC input voltage, and two-phase induction [12]-[13] or synchronous [14], [15] motors. Using half-bridge connection for both inverter and matrix converters the number of power switching elements of the two-stage converter can be reduced and smaller then those of classical three-phase voltage inverter. Let's notice that switching-off process is provided by AC interlink, so switching-off losses are minimized, and the efficiency can be higher then classical connection one.

Experimental verification of torque-speed characteristic of used split-single phase IM shows good agreement between experimental results and the theoretical- and simulation analysis results. Based on this it is possible to provide the design and power dimensioning of the 2-phase electronic driving system as an alternative propulsion system for EV.

Appendix

Parameters of the investigated motor (the real name-plate):

P_N[W]	V_N[V]	n_N[rpm]	I_N[A]	T_N[Nm]
150	230	2730	1.0	0.55

Parameters used in simulation are:

	R_s [Ω]	R'_r [Ω]	$X_{\sigma s}$ [Ω]	Method	X_m (Ω)	L_m (H)
	19.92	50.1	21.37	Classical	374.9	1.1933
	X'_r [Ω]	L_s [H]	L'_r [H]	Suhr´s	233.5	0.7417
D winding	21.37	0.0679	0.0679	Two-phase	452	1.4388
	R_s [Ω]	R'_r [Ω]	$X_{\sigma s}$ [Ω]	FEM	398.5	1.2599
	21.32	51.1	22.3			
	X'_r [Ω]	L_s [H]	L'_r [H]			
Q winding	22.3	0.0709	0.0709			

Acknowledgement

The authors wish to thank for the financial support to R&D operational program Centre of excellence of power electronics systems and materials for their components No. OPVaV-2008/2.1/01-SORO, ITMS 26220120003 funded by European regional development fund (ERDF) and VEGA Agency for the project No. 1/0470/09.

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