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An Alternate Approach to Overcome Problems in Vector Control of Single Phase Induction Motor

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Abstract— This paper presents several of the problems encountered with vector-controlled single-phase induction motor (SPIM), and discusses about the complex implementation of a vector controlled SPIM drive. The vector-controlled symmetrical two-phase induction motor (TPIM) is presented as a viable replacement for the vector-controlled SPIM. The implementation of the proposed vector-controlled TPIM is simple compared to the vectorcontrolled SPIM. All the TPIM parameters can be calculated simply and precisely. The proposed strategy for TPIM is derived from the indirect vector control strategy used for three-phase ac machines. Several differences between the vector control strategies for the TPIM and for three-phase ac motor are discussed. The validity of the proposed vector-controlled TPIM was verified by simulations.

Index Terms— Vector-controlled single-phase induction motor (SPIM), vector-controlled two-phase induction motor (TPIM), unsymmetrical motor.

1 INTRODUCTION

Single-phase induction motors (SPIMs) are employed widely in the fractional power range, particularly in households where a three-phase ac electrical supply is not available. SPIMs are used typically to maintain a constant speed, for example, in fans and vacuum cleaners. SPIMs normally require auxiliary winding and main winding as well as a capacitor to produce the starting torque. SPIMs are typically classified according to their starting technique: split-phase motor, capacitor (capacitor-run or capacitor-start) motor, and shaded-pole motor [1]. Fig.1 shows typical speed control of SPIMs by voltage control using the power switches. Fig. 1(a) shows a triac-controlled strategy that adjusts the supplied voltage to the capacitor motor according to the load conditions. The capacitor in a capacitor motor causes an auxiliary phase current to lead the main phase voltage, creating a large angle of displacement between the currents in the two windings. This strategy can only control the speed of the capacitor motor over a narrow range owing to its fixed synchronous frequency. Since SPIMs are used in a range of applications at low power levels, the necessity of higher power efficiency and a workable adjustable speed control are of great importance [2]. Fig. 1(b) shows a two-leg inverter connected to an SPIM. When this inverter is used, the speed of the SPIM can be controlled over a wide range by adjusting the frequency.

Several studies have concentrated on vector control strategies for SPIMs (as "vector-controlled SPIM") [4]–[10] because they are used widely. On the other hand, the SPIMs are classified as unsymmetrical two-phase induction motors (TPIMs) because the parameters of the main and auxiliary windings are not identical.

Therefore, when the SPIM is operated by the vector control strategy, significant problems are generated due to unbalanced operation. This paper presents several problems encountered in conventional vector-controlled SPIMs and proposes a vector control strategy for a symmetrical two-phase induction motor (TPIM) drive (as vector-controlled TPIM) as a viable replacement for the vector-controlled SPIM. The implementation of the vector-controlled TPIM is simpler and more accurate than a vector-controlled SPIM because symmetrical TPIM are used instead of unsymmetrical SPIM. The vector control strategy for a TPIM drive is derived from the vector control strategies used in three-phase ac motor drives [11], [12]. The validity of the proposed symmetrical TPIM vector control strategywas verified by using MATLAB simulation.

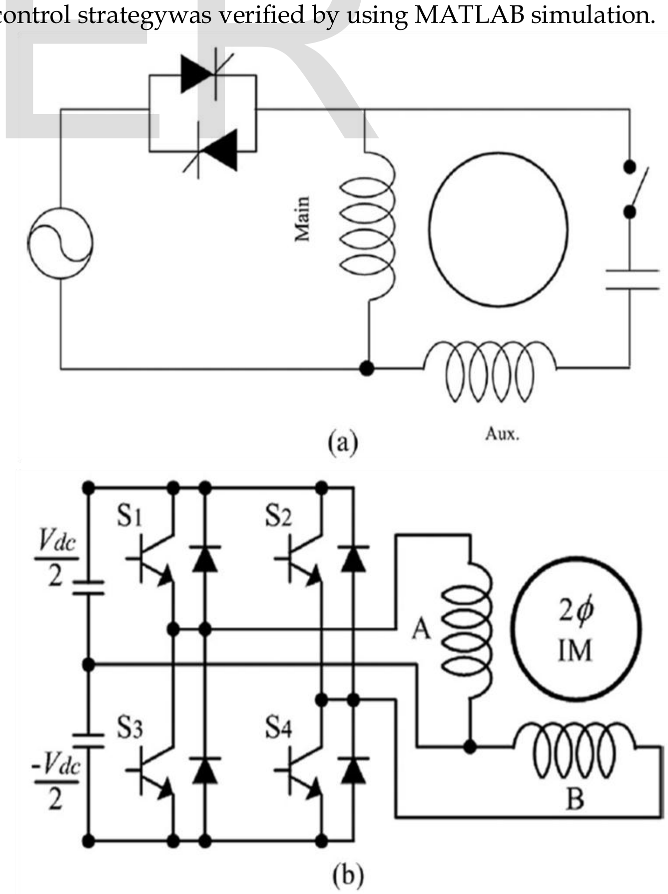

Fig. 1. Power converter for an SPIM drive. (a) AC voltage con-

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troller by triac. (b) Two-phase half-bridge inverter.

2 CONVENTIONAL VECTOR-CONTROLLED SPIM MODEL

2.1 SPIM Model

SPIMs are classified as unsymmetrical TPIMs. Fig. 2 shows the dq-axis equivalent circuit of an unsymmetrical TPIM in terms of the stationary reference frame [13]. This equivalent circuit is more complicated than that of three-phase induction motors because the auxiliary winding has more turns than the main winding. The dynamic SPIM model neglecting core saturation and iron losses can be described using a stationary reference frame [13].

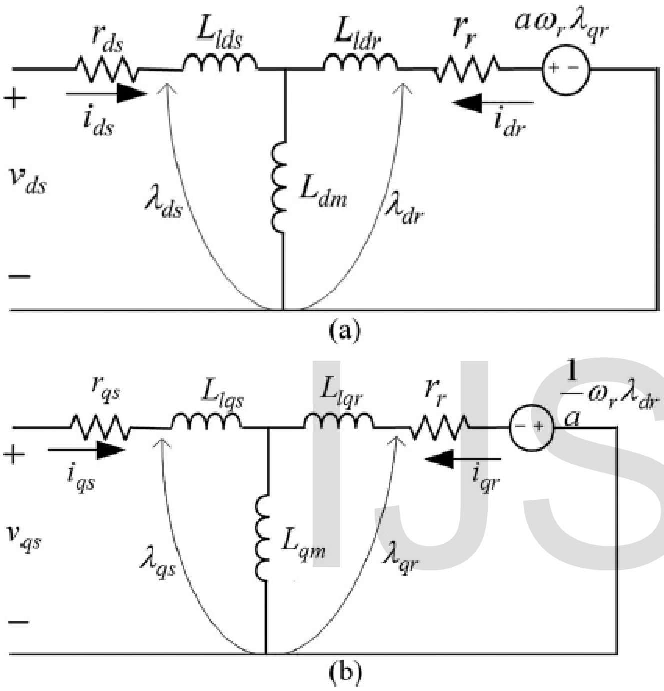
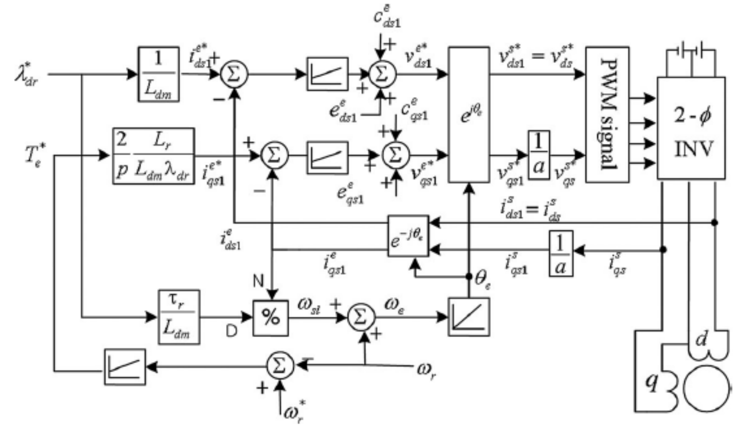


Fig. 2. Equivalent circuit of an unsymmetrical TPIM in a stationary reference

2.2 Modified SPIM Model

Many studies have concentrated on modified SPIM models to eliminate the unbalanced operation. This section examines one of the SPIM models, which was presented by Correa [6]. The mutual inductances are not identical in the torque (6). The ac term of the electromagnetic torque can be eliminated by adjusting the stator currents frame.

Fig. 3 illustrates the implementation of the vector-controlled SPIM using the indirect field orientation. SPIM model is almost symmetrical when the machine undergoes an



unbalanced operation only due to the turn ratio of the two windings. On the other hand, modeling of SPIM involves mathematical problems.

Fig. 3. Implementation of the vector-controlled SPIM drive using the indirect field orientation.

3 PROBLEMS IN VECTOR-CONTROLLED SPIM DRIVES AND ITS MANUFACTURING COSTS

The capacitor motor is ordinarily used in the implementation of vector-controlled SPIMs because of their availability. The SPIM has different winding turns and wire diameters in their main windings and auxiliary windings. Therefore, electromagnetic theory states that the primary resistances of the main windings and auxiliary windings are proportional to the winding turns, and are inversely proportional to their wire area [14]. This means that the parameters of the two windings are not identical causing several problems in SPIMs used as unsymmetrical TPIMs.

A. Problems Found in SPIM Model Equations

The SPIM modeling which apply to the unsymmetrical ac machine, are defined by employing a stationary reference frame. The mathematical problems regarding the conventional vector-controlled SPIM are analyzed in this section. The SPIM model can be analyzed classically by revolvingfield theory [1]. Fig. 4 shows the equivalent circuit of the main winding (or d-axis) when an unbalanced stator voltage is supplied to the SPIM.

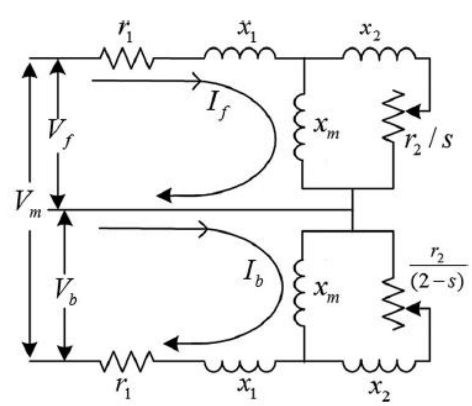


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Fig. 4. Equivalentmain winding circuit for SPIM under unbalanced operation

B Complex Implementation of the Vector-Controlled SPIM

Conventional vector-controlled SPIM methods have concentrated mostly on eliminating unbalanced operation because vector control strategies are based on a balanced drive system involving symmetrical motors. Therefore, the implementation of a vector-controlled SPIM drive is more complex than that a vector-controlled symmetrical motor.

C DIFFICULTY IN MEASURING THE SPIM PARAMETERS

The parameters for ac machines need to be measured precisely to operate a vector-controlled ac machine without error. The parameters for symmetrical machines can be calculated precisely using the no-load test and locked-rotor test. On the other hand, unsymmetrical motors produce negative and positive torque during operation. This makes measuring the parameters more complicated [1].

In addition, modeling, renewing, and optimizing single-phase capacitor motors are difficult compared to symmetrical motors [17], [18]. Therefore, many calculations and iterations of measuring tests are needed to determine the SPIM parameters. In [18], numerous computer calculations were proposed to obtain precise measurements of the SPIM parameters. Therefore, unsymmetrical machines as SPIM is not proper to control the speed motor by using a vector control strategies, and symmetrical motors should be used as a replacement.

D DIFFICULTY IN CALCULATING THE TURN RATIO

The turn ratio of a SPIM is ordinarily defined as the ratio of the main winding turns to the auxiliary winding turns. But it is precisely defined as the ratio of the effective main winding turns to the effective auxiliary winding turns. If the value of turns ratio of aSPIM is not exact, the implementation of the vector-controlled SPIM shown in Fig. 3 cannot maintain balanced operation.

Although the characteristics of the SPIM are poor, vector control strategies for SPIM have been attempted because SPIMs are used widely and are inexpensive. Researchers, however, need to make a special order to acquire TPIMs for their experiments because the TPIMs are not manufactured.

Therefore, the TPIM cost is higher than SPIM due to customization, but it is not overly high because a TPIM can be constructed using the same facilities as an SPIM or a three-phase induction motor. If TPIMs become popular, the real cost of a TPIM will be lower than that of an SPIM because the TPIM does not require a capacitor. On the other hand, special motor drives, for example, the five-phase induction motor and synchronous reluctance motor drives, which have not been manufactured in any quantity until now, have been studied for future use owing to their advantages.

4 VECTOR CONTROL STRATEGY FOR TPIM DRIVE

This section proposes a vector control strategy for symmetrical TPIMs (as " vector-controlled TPIM ") as a replacement for the vector-controlled SPIM. Historically, the vector control strategies have concentrated on three-phase ac machines and have not been attempted in symmetrical TPIM until now. The vector-controlled TPIM can solve several of the problems that plague the vector-controlled SPIM, and can control the speed of the TPIM precisely.

A. TRANSFORMATION OF PHASE CURRENT EQUATIONS

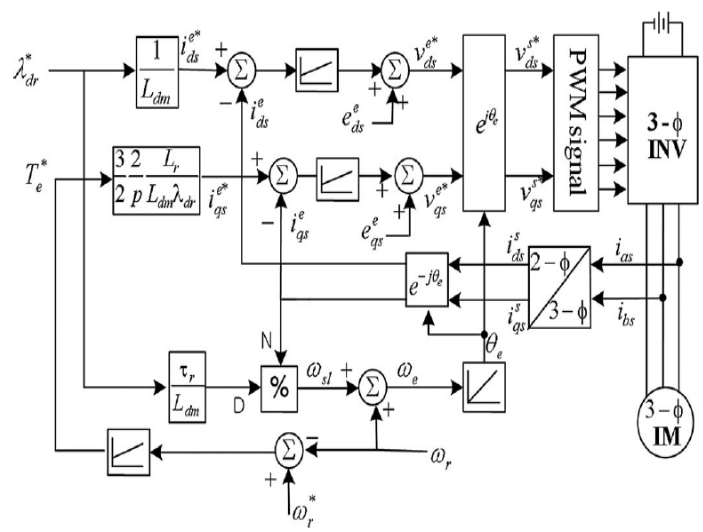
The phase current equations in terms of the stationary reference frame must be transformed to that in terms of the synchronous reference frame in the vector control.

B. SYMMETRICAL TPIM MODEL

Symmetrical TPIMs have two identical stator windings that are arranged in an electrical quadrature. Since the rotor windings are forged as a squirrel cage, the parameters of dq-axis are identical to each other

C. INDIRECT VECTOR CONTROL FOR SYMMETRICAL TPIM

Vector control strategies have been developed focusing on three-phase ac motors [11]. On the other hand, the vectorcontrolled TPIM as a replacement for vector-controlled SPIM has not been proposed until now, even though it is similar to the vector-controlled three-phase ac motors. This paper proposes a simple



indirect vector control strategy for TPIM, which can be applied to the low-power motor drive system. The currents supplied to the machine need to be oriented in phase and in quadrature for the rotor flux. Fig. 5 shows the implementation of the indirect vec-

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torcontrolled TPIM drive.

Fig. 5 Implementation of a indirect vector-controlled three-phase ac motor

D. Differences Between the Vector-Controlled TPIM and the Vector-Controlled Three-Phase AC Motor

The vector control strategy for symmetrical TPIM is derived from the vector-controlled three-phase ac machine. Three-phase ac motors are operated by a rotating mmf. The abc→dq transformation and inverse transformation are omitted in the implementation of the indirect vector-controlled TPIM, as shown in Fig. 3, whereas transformations are needed in the indirect vector-controlled three-phase ac machine, as shown in Fig. 5. Two output currents in a TPIM drive system can be measured using only a single current sensor [19], whereas the three output currents can be measured using two current sensors in a three-phase acmotor drive system.

The arrangement of two stator windings in the slots of

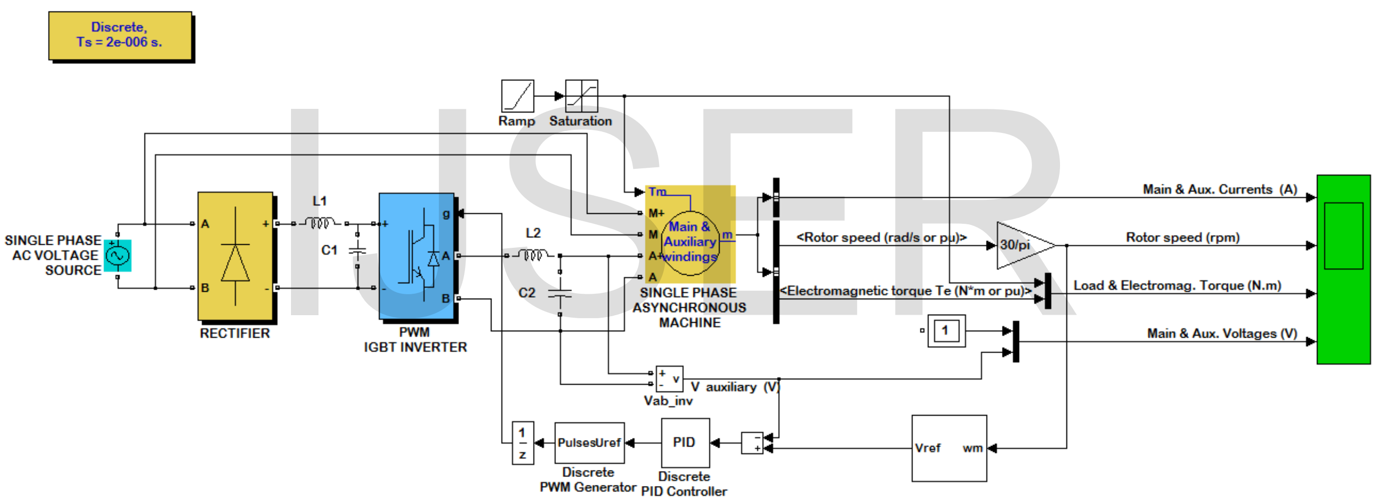
Fig. 7 SIMULINK model of single

5 SIMULATION RESULTS

The proposed strategy was verified by simulations using MATLAB. Table I lists the parameters of the TPIM model (rated voltage: 220 V, rated current: 5 A, rated power: 1.4 kW, rated speed: 1760 r/min, and the number of poles: 4), which can be calculated using the no-load test and locked-rotor test. Fig. 6 shows the SIMULINK model of the voltage controlled single phase induction motor drive.

The proposed vector control strategy is useful for low-power motor drives and in areas where a single-phase voltage source is available. The validity of the vector control strategy for the symmetrical TPIM was verified through simulations.

The vector-controlled TPIM was derived from the indirect vector control concept for three-phase ac machines. In add



TPIM is simpler compared to three-phase ac machines. Therefore, the TPIM drive system is useful in low-power motor drive applications and in areas where only a single-phase voltage source is available.

tion, several differences between the control strategies for the SPIM and three-phase ac motors were explained.

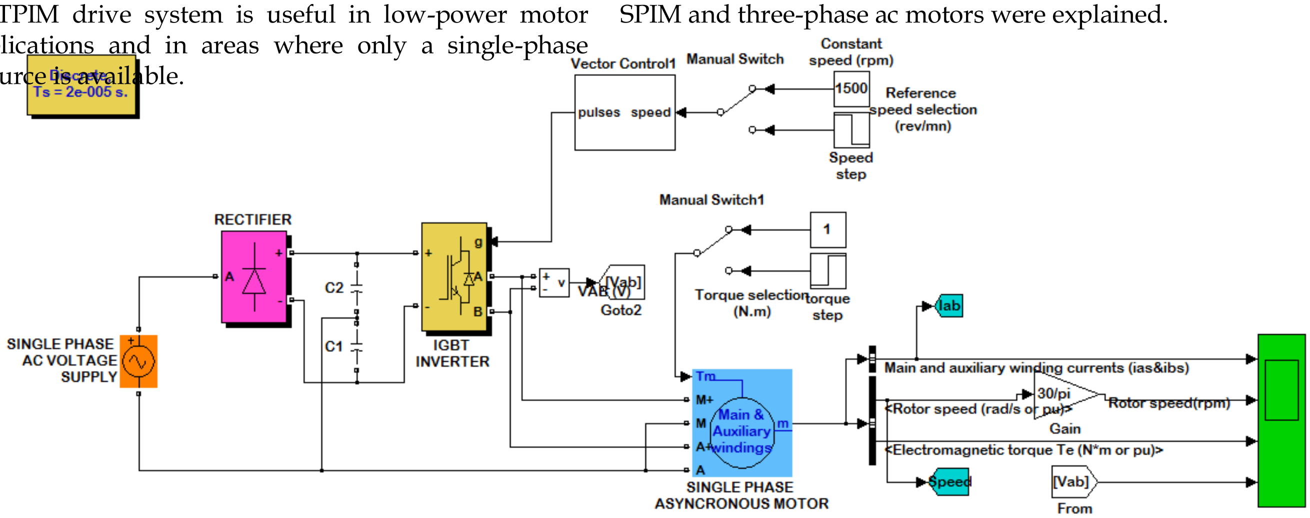


Fig. 6 SIMULINK model of single phase voltage controlled induction motor

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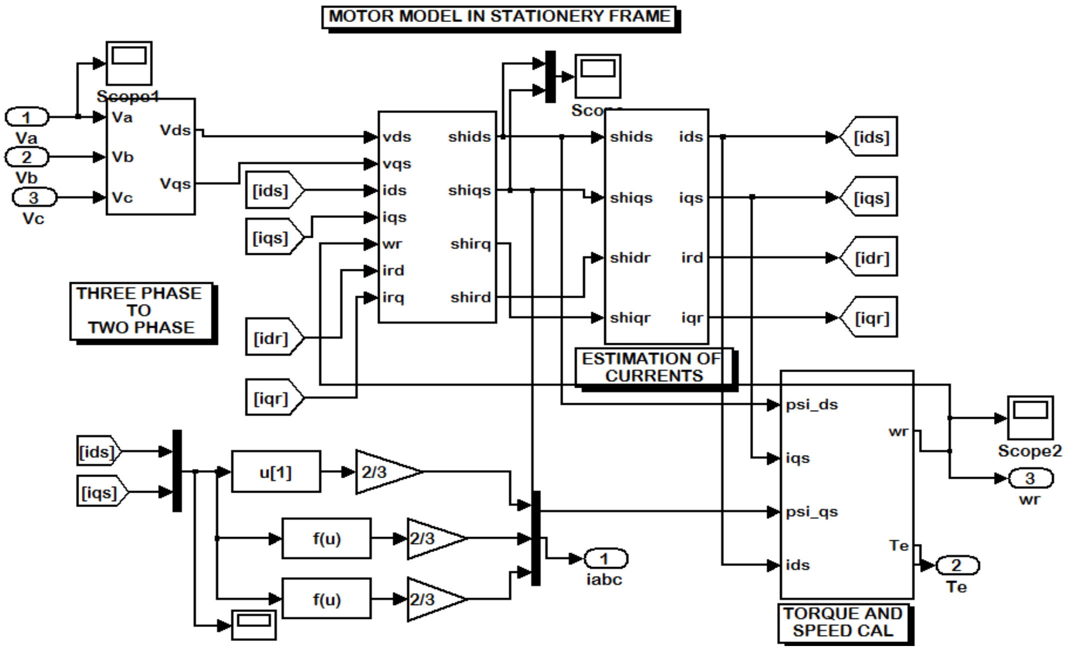

Fig. 8 SIMULINK model of two phase induction motor in stationery reference frame

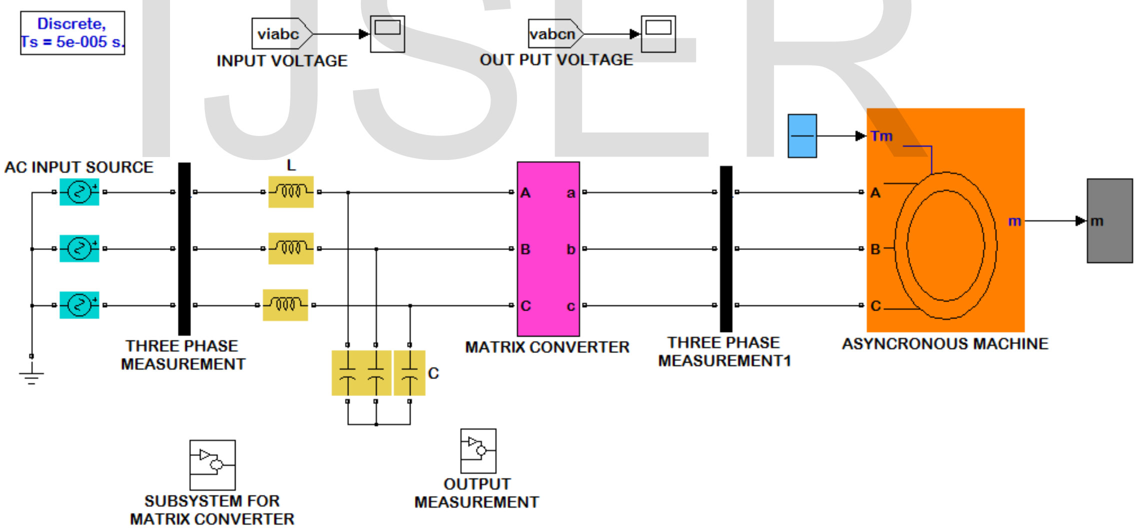

Fig. 9 SIMULINK model of DTC of three phase induction motor using SVM based matrix converter

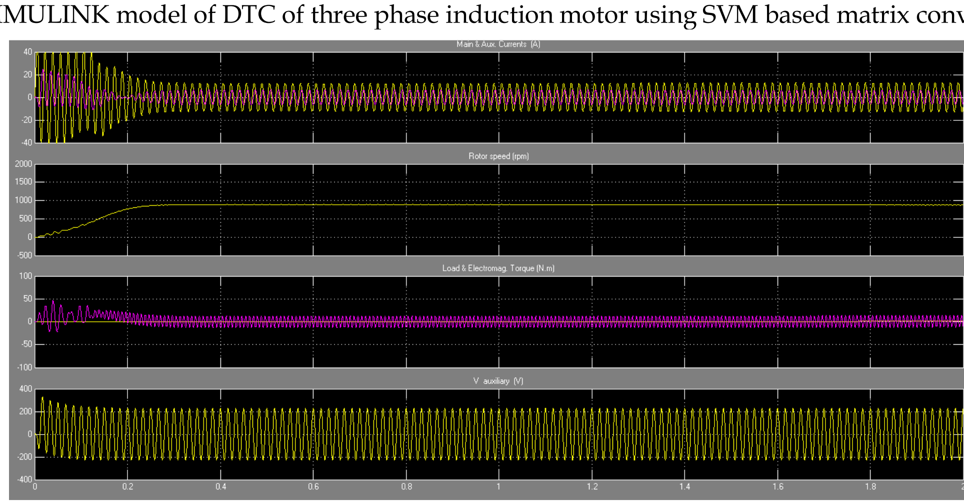

Fig. 10 Output waveforms for current, Torque, speed and voltage of DTC of two phase induction motor

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6 CONCLUSION

This paper presented the problems encountered in the conventional vector-controlled SPIM, and explained that the vector control strategies for the SPIM drive are not needed in the low power level field. The vector-controlled TPIM was presented as a replacement for the vector-controlled SPIM. The proposed vector-controlled TPIM has several advantages. The implementation of the proposed vector-controlled TPIM is simpler than that of the vector-controlled SPIM. The parameters of the TPIM can be calculated simply, whereas parameter measurements for an SPIM are difficult. The vector controlled TPIM is useful to the low power motor drive applications at area where the voltage source in the drive system can be supplied by the dc battery or single-phase ac voltage source.

The vector-controlled TPIM was derived from the indirect vector control concept for three-phase ac machines. In addition, several differences between the vector control strategies for the TPIM and three-phase ac motors were explained.

The proposed vector control strategy is useful for low-power motor drives and in areas where a single-phase voltage source is available. The validity of the vector control strategy for the symmetrical TPIM was verified through simulations using MATLAB/SIMULINK.

REFERENCES

[1] Cyril G. Veinott, Theory of Design of Small Induction Motors. New York: McGraw-Hill, 1959.
[2] F. Blaabjerg, F. Lungeanu, K. Skaug, and M. Tonnes, "Two-phase induction motor drives," IEEE Ind. Appl. Mag., vol. 10, no. 4, pp. 24–32, Jul./Aug. 2004.
[3] C. Mdemlis, I. Kioskeridis, and T. Thodoulidis, "Optimization of singlephase induction motors—Part I: Maximum energy efficiency control," IEEE Trans. Energy Convers., vol. 20, no. 1, pp. 187–195, Mar. 2005.
[4] M. F. Rahman and L. Zhong, "A current-forced reversible rectifier fed single-phase variable speed induction motor drive," in Proc. 27th Annu. IEEE Power Electron. Spec. Conf., Jun., 1996, pp. 114–119.
[5] M. B. R. Correa, C. B. Jacobina, A. M. N. Lima, and E. R. C. da Silva, "Field oriented control of a single-phase induction motor drive," in Proc. IEEE Power Electron. Spec. Conf., May 1998, pp. 990–996.
[6] M. B. R. Correa, C. B. Jacobina, A. M. N. Lima, and E. R. C. da Silva, "Rotor-flux-oriented control of a single-phase induction motor drive," IEEE Trans. Ind. Electron., vol. 47, no. 4, pp. 832–841, Aug. 2000.
[7] M. B. R. Correa, C. B. Jacobina, and E. R. C. da Silva, "Vector control strategies for single-induction motor drive system," IEEE Trans. Ind. Electron., vol. 51, no. 5, pp. 1051–1080, Oct. 2004.
[8] S. V. Zadeh and S. Harooni, "Decoupling vector control of single phase inductionmotor drives," in Proc. IEEE Power Electron. Spec. Conf., 2005, pp. 733–738.
[9] D.Wang, "Hybrid fuzzy vector control for single phase induction motor," in Proc. Int. Conf. Comput. Control Ind. Eng., 2010, pp. 122–125.
[10] A. Nied, J.Oliveira, F. R. L. Sa, R. Campos, and L. H. R. C. Stival, "Singlephase induction motor indirect field oriented control under nominal load," in Proc. Power Electron. Drive Syst., 2010, pp. 789–793.
[11] A. M. Trzynadlowsky, The Field Orientation Principle in Control of Induction Motors. Norwell, MA: Kluwer, 1994.
[12] V. T. Phan, H. H. Lee, and T. W. Chun, "An improved control strategy using a PI resonant controller for an unbalanced stand-alone doubly-fed induction generator," J. Power Electron., vol. 10, no. 2, pp. 194–202,2011.
[13] Paul C. Krause, Analysis of Electric Machinery. New York: McGraw- Hill, 1987.
[14] G. R. Slemon and A. Straughen, Electric Machinery. Reading, MA: Addison-Wesley, 1980.
[15] D.-H. Jang and D.-Y. Yoon, "Space vector PWMtechnique for two-phase inverter-fed two-phase inductionmotors," IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 542–549, Mar./Apr. 2003.
[16] A. M. A. Jabbar, A. M. Khambadkone, and Z. Yangfeng, "Space-vector modulation in a two-phase induction motor drive for constant-power operation," IEEE Trans. Ind. Electron., vol. 51, no. 5, pp. 1081–1088, Oct. 2004.
[17] C. Attaianese, A. Del Pizzo, E. Pagano, and A. Perfetto, "Modelling, renewing and optimizing single-phase capacitor motors for home applications," in Proc. IEEE Ind. Appl. Soc. Conf. Rec, 1986, pp. 831–839.
[18] E. F. Fuchs, A. J. Vandenput, J. Holl, and J. C. White, "Design analysis of capacitor-run single-phase induction motors," IEEE Trans. Energy Convers., vol. 5, no. 2, pp. 327–336, Jun. 1990.
[19] Y. H. Cho, K. Y. Cho, H. S. Mok, K. H. Kim, and J. S. Lai, "Phase current reconstruction techniques for two-phase in-

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ISSN 2229-5518

verters using a single current sensor," J. Power Electron., vol. 11, no. 6, pp. 837–845, 2011.
[20] D.-H. Jang, "PWM methods for two-phase inverters," IEEE Ind. Appl.Mag., vol. 13, no. 2, pp. 50–61, Mar./Apr. 2007.