A Direct Torque Control Scheme for Five-phase Induction Motor Drive with Reduced Current Distortion

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ABSTRACT

This poster presents a direct torque control for five-phase induction motor with constant switching frequency and reduced stator current distortion. M. Depenbrock, I. Takahashi and T. Noguchi proposed Direct torque control (DTC) for 3-phase induction machines in the mid 1980. DTC has been gaining more popularity due to its exceptional dynamic response, less dependence on machine parameters and simple control architecture. DTC utilizes the hysteresis band control which is one of the simplest and popular control scheme. The major problems in the conventional DTC scheme is large torque ripple, stator current distortion and variable switching frequency. This project work presents a DTC scheme for five-phase induction motor drive to achieve constant switching frequency and minimum distortion in the stator current. The proposed DTC scheme is validated by extensive simulation on a Matlab-Simulink platform and experimental results. The DTC control algorithm was implemented using TMS320F28377S digital signal controller

FIVE PHASE VSI FED INDUCTION MOTOR

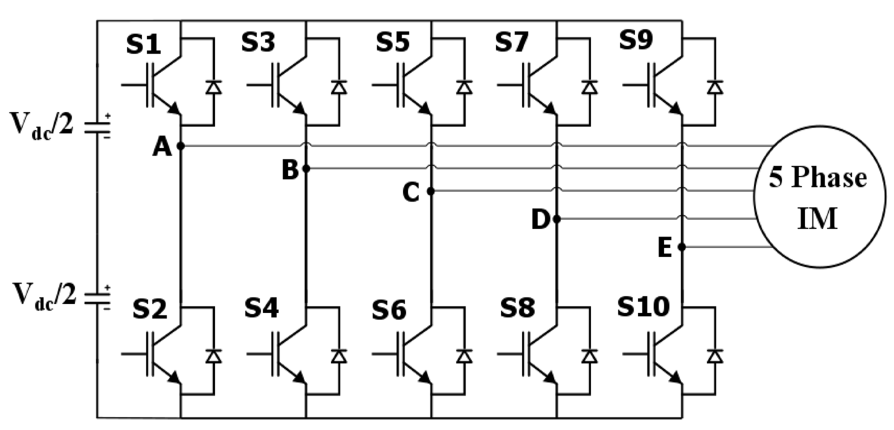

Fig.1: Five-phase VSI fed Induction Motor

Each switching state of inverter corresponds to a voltage space vector. The magnitude of space vector in α-β and x-y plane is given by,

$$V_{\alpha-\beta} = \frac{2}{5}(V_A + aV_B + a^2 V_C + (a^*)^2 V_D + a^* V_E)$$

$$V_{x-y} = \frac{2}{5}(V_A + (a^*)^2 V_B + aV_C + a^* V_D + a^2 V_E)$$

SPACE VECTOR DIAGRAM OF FIVE PHASE INVERTER

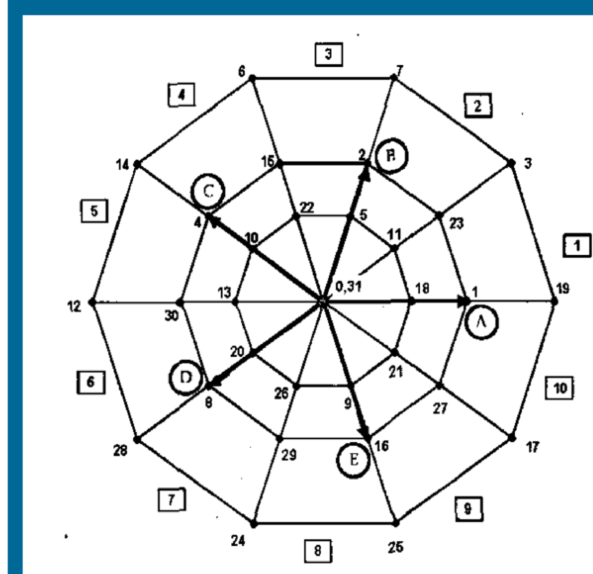

Fig.2: Space vector diagram in α-β plane

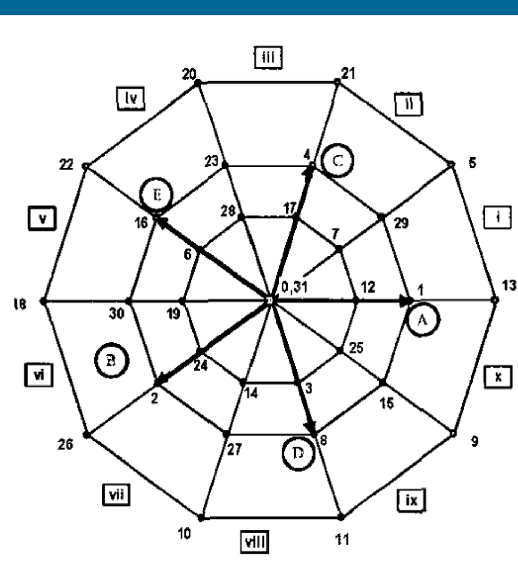

Fig.3: Space vector diagram in x-y plane

3 Concentric decagon formed by large, medium and small voltage space vectors. Five-phase motor variables are transformed into α-β and x-y plane. α-β plane components produces torque and rotating magnetic field. x-y plane components are responsible for distortion in waveform.

PWM SCHEME FOR X-Y VOLTAGE ELIMINATION

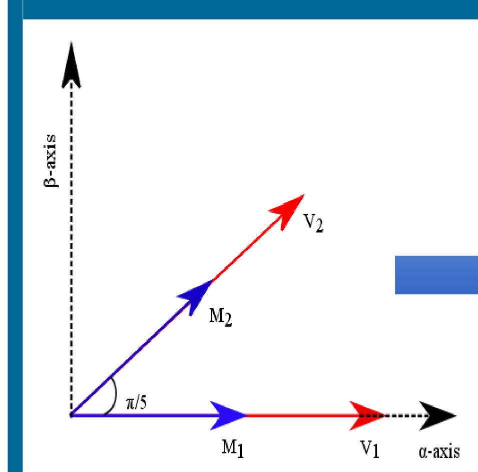

Fig.4: Large and medium voltage space vectors in sector-1 of α-β plane

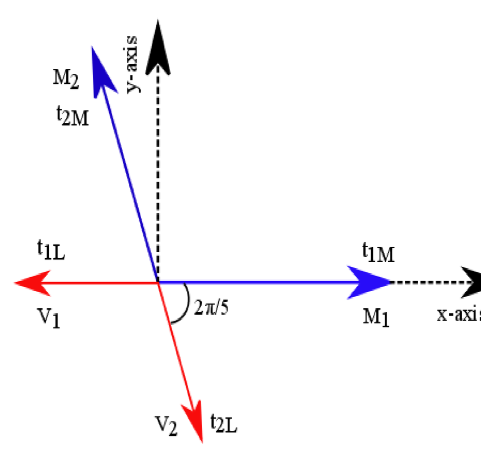

Fig.5: Sibling vectors of Fig.4 in x-y plane

Each inverter state in α-β has a sibling vector in x-y plane. Switching is done by any 2 large and 2 medium voltage space vectors in such a way that their corresponding sibling space vectors in x-y plane are opposite to each other.

VIRTUAL VOLTAGE SPACE VECTOR

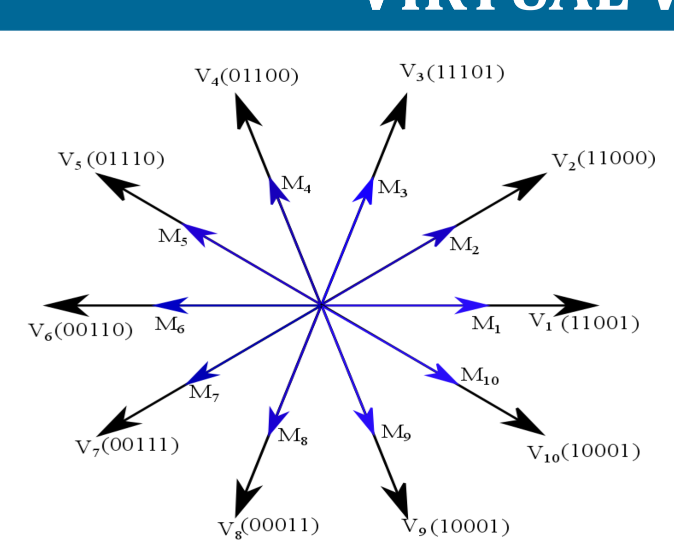

Fig.6: Actual large and medium voltage space vectors in 5- phase VSI

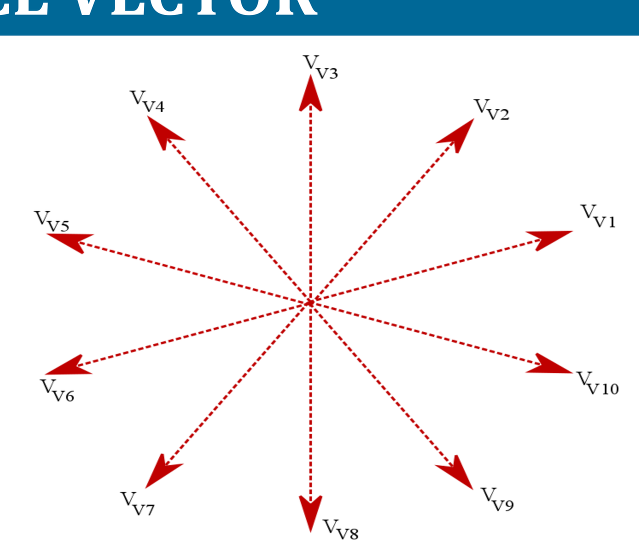

Fig.7: Virtual voltage space vectors in 5-phase VSI

Virtual voltage space vectors are realized by switching large and medium voltage space vectors maintaining a particular ratio for dwell time so that average voltage in the (x-y) plane is zero. The new virtual voltage space vector diagram has a shift of 18 degrees from the five-phase VSI space vector diagram.

REALIZATION OF VIRTUAL VOLTAGE SPACE VECTORS

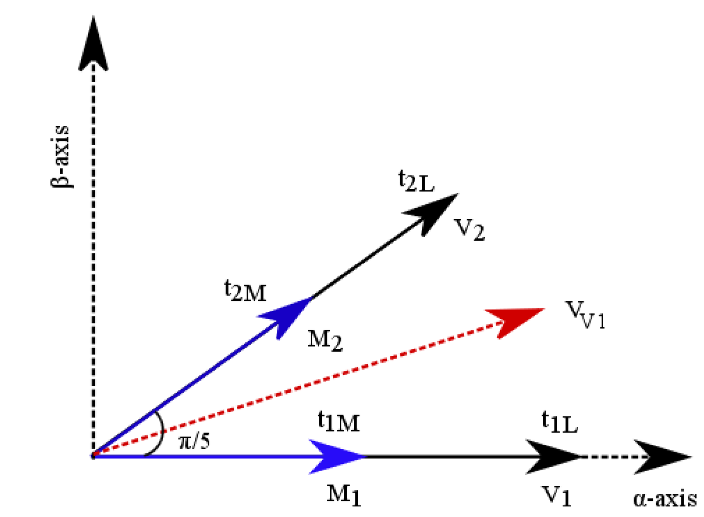

Fig.8: Virtual voltage space vector and corresponding large and medium space vectors in α-β plane

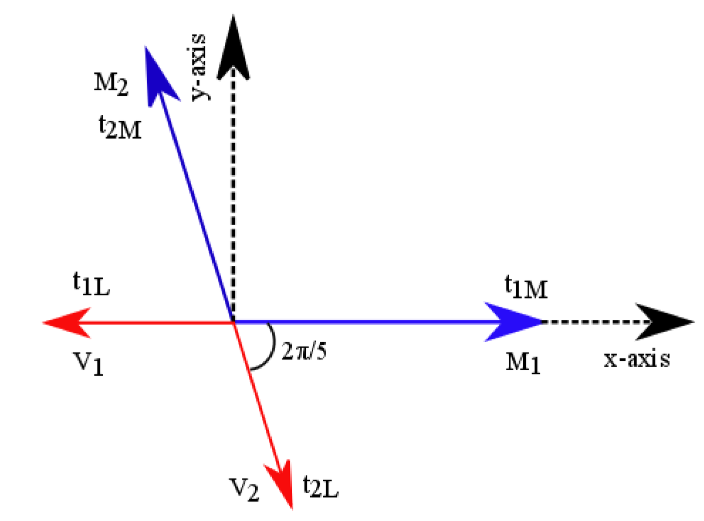

Fig.9: Mapping of space vectors shown in Fig.4. into x-y plane

61.8% of the total time is allocated to large space vectors and 38.2% to the medium space vectors.

DIRECT TORQUE CONTROL SCHEME

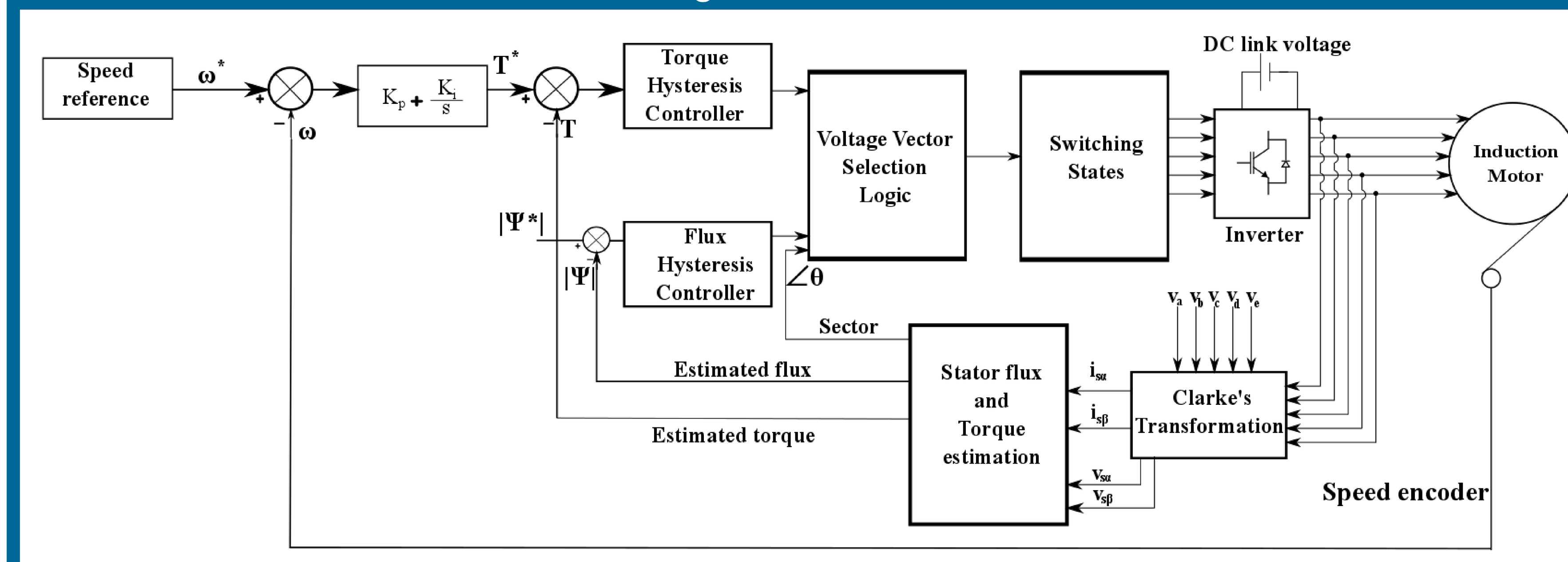

Fig.10 Block diagram of direct torque control of five-phase induction motor

SIMULATION AND EXPERIMENTAL RESULTS

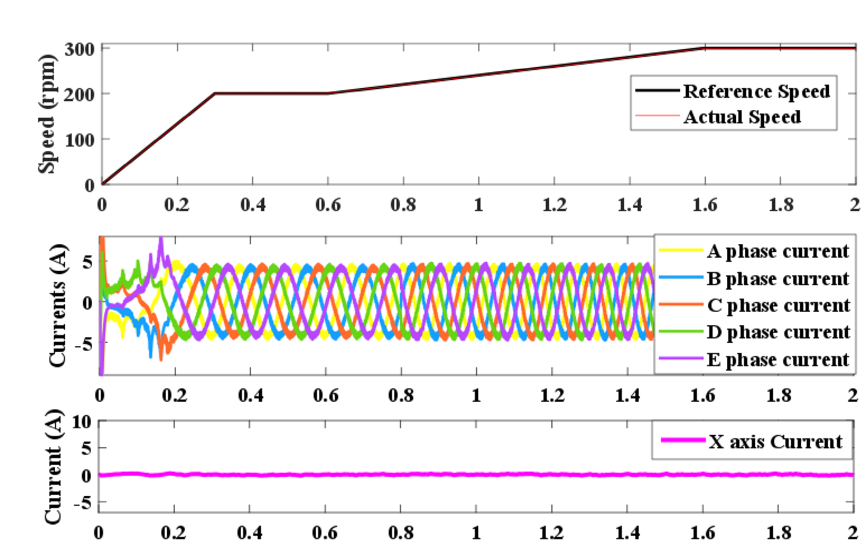

Fig.11 Simulation results of loaded condition: 1. Actual speed and reference speed(rpm) (b) Five stator phase current (c) X -axis current

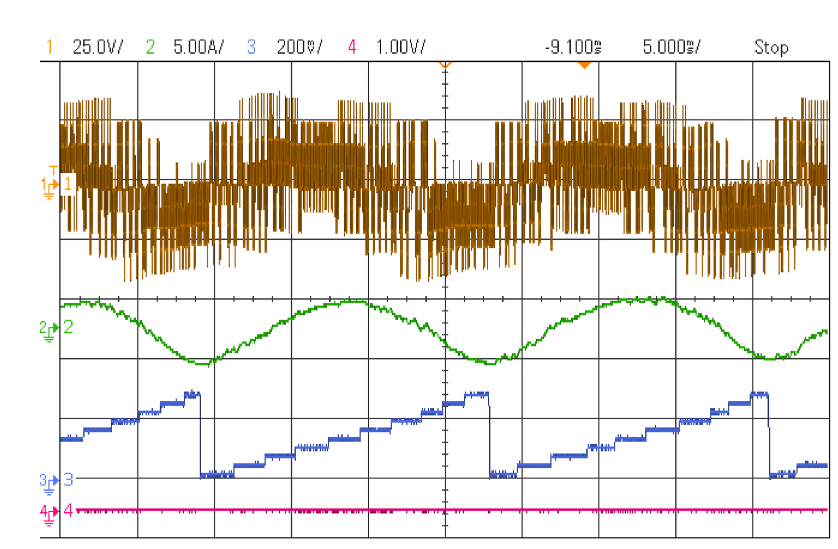

Fig.13 Steady state experimental result : 1. Phase-A Voltage (Y axis 25V/div), 2. Phase-A Current (Y axis 5A/div), 3. Sector information (0-10), (X axis 5.0 Ms/div) 4. Stator X-axis Average Voltage(Y axis 1V/div),(X axis 5.0 Ms/div).

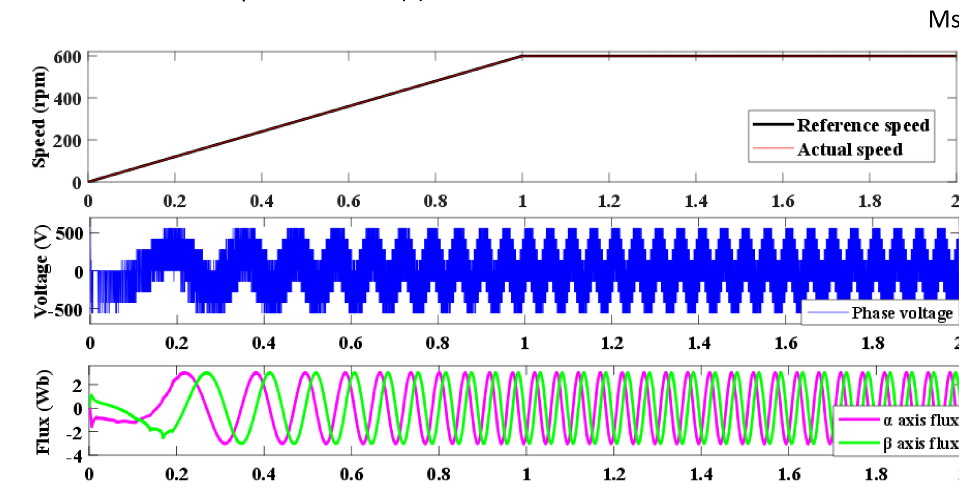

Fig.12 Simulation results during no load operation: 1. Actual speed and reference speed(rpm) 2. Phase voltage (Volts) 3. Flux (Weber)

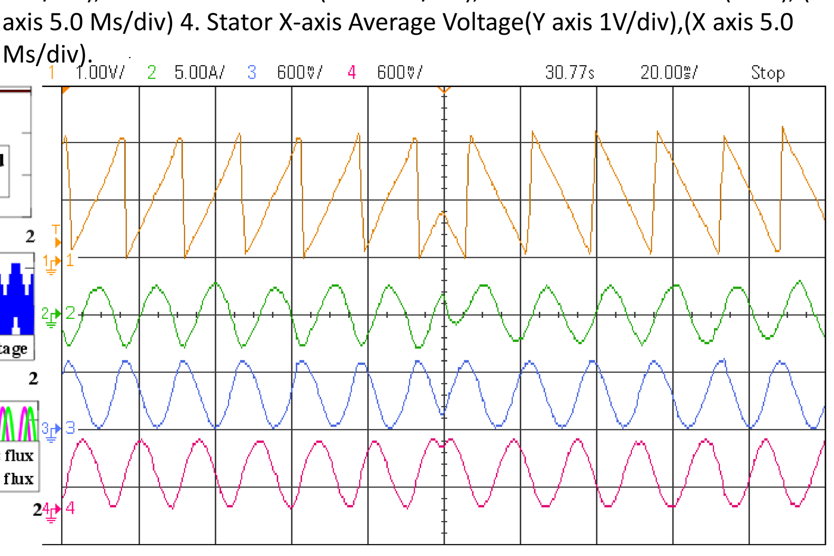

Fig.14 Experimental result during speed reversal: 1. Stator flux angle (Y axis 3.14rad/div), (X axis 20.0 ms/div) 2. Phase-A current (Y axis 5A/div), 3. Alpha-axis stator flux,(X axis 20.0 ms/div) 4. Beta-axis stator flux,(X axis 20.0 ms/div).

KEY REFERENCES

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2. Huangsheng Xu, H. A. Toliyat and L. J. Petersen, "Five-phase induction motor drives with DSP-based control system," in IEEE Transactions on Power Electronics, July 2002.

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