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MODELLING AND SIMULATION OF A HYBRID STEPPER MOTOR IN MICROSTEPPING MODE

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ABSTRACT

Stepper motors are commonly used in robotic systems and in positioning applications. Low cost, low maintenance requirement and durability makes the stepper motor an ideal choice for positioning applications. Microstepping is a mode of excitation of stepper motor in which currents in the two phases will be sinusoidals with phase shift. Microstepping enables smooth operation of motor with increased position resolution. The number of steps will be increased and it eliminates resonance problems. This paper describes the mathematical modelling and microstepping operation of a hybrid stepper motor. The open loop microstepping of a hybrid stepper motor with pulse width modulation using double H-bridge has been simulated in MATLAB-SIMULINK.

Keywords: H-Bridge, Microstepping, Stepper Motor.

I. INTRODUCTION

Stepper motor is an incremental motion electromechanical device which is commonly used in positioning applications. They are used in a variety of applications, including computer peripherals, machine tools, robotics etc. Stepper motors are also used in biomedical applications like medical scanners, fluid pumps etc. Stepper motors require less maintenance and they are durable. Stepper motors can operate in open-loop or closed-loop mode. The rotation of the stepper motor is proportional to the number of input pulses applied to its phases. Hybrid stepper motor is a stepper motor with a permanent magnet rotor. Core of the rotor has a cylindrical shaped magnet[1].

The stepper motor can be operated in three different stepping modes namely full-step, half-step and microstep. Microstepping has many advantages compared to other modes of excitation. It is implemented by partially exciting different phase windings at the same time. Current in the motor winding is adjusted so that it looks similar to a sine wave. Current sent to the two windings will be always out of phase with each other. Microstepping is used in applications that require accurate positioning [2],[3],[4]. Microstepping increases the rotor position resolution and motion stability.

II. MODELLING OF HYBRID STEPPER MOTOR

The mathematical modelling equations for a hybrid stepper motor are given below[5]. This is the dynamical model with differential equations. Equations (1) and (2) are the electrical equations and (3) and (4) are the mechanical equations of the hybrid stepper motor. The change in inductance, detent torque and magnetic coupling between the phases are neglected in this model.

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$$\frac{di_a}{dt} = \frac{u_a + K_m \omega \sin(N\theta) - Ri_a}{L} \qquad (1)$$

$$\frac{di_b}{dt} = \frac{u_b + K_m \omega \cos(N\theta) - Ri_b}{L} \qquad (2)$$

$$\frac{d\omega}{dt} = \frac{K_m i_b \cos(N\theta) - T_L - K_m i_a \sin(N\theta) - K_v \omega}{J} \qquad (3)$$

$$\frac{d\theta}{dt} = \omega \qquad (4)$$

where i_a (A) is the current in phase A, i_b (A)is the current in phase B, u_a(V) is the voltage in phase A, u_b(V) is the voltage in phase B, ω is the rotor speed(rad/sec), T_L is the load torque(Nm) and ϴ is the rotor position(rad). The parameters of hybrid stepper motor used in the simulation are given in TABLE. 1. Fig 1 shows the subsystem of currents based on the motor equations (1) and (2). Fig 2 shows the subsystem of speed and position based on the motor equations (3) and (4).

Table 1: Motor Parameters

Parameters	Specification
Phase resistance, R	1.13Ω
Phase inductance, L	3.6mH
Inertia of motor, J	0.000048kgm^2
Number of rotor teeth, N	100
Coefficient of viscous friction, K_v	0.0014N.m.s/rad
Torque constant, K_m	0.458Nm/A

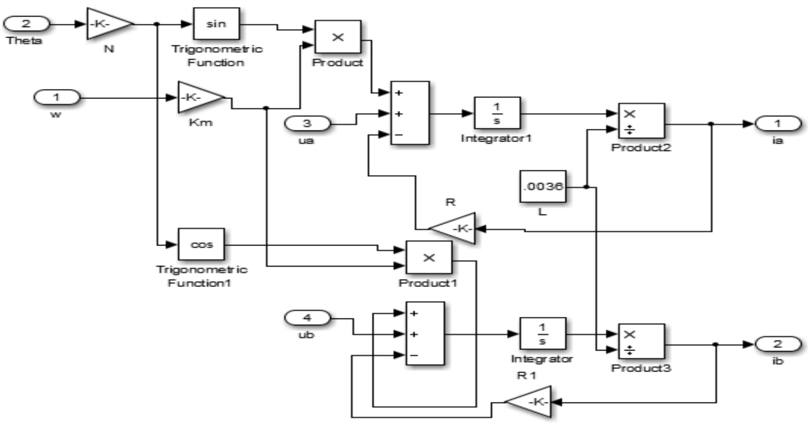

Fig 1: Subsystem of Currents

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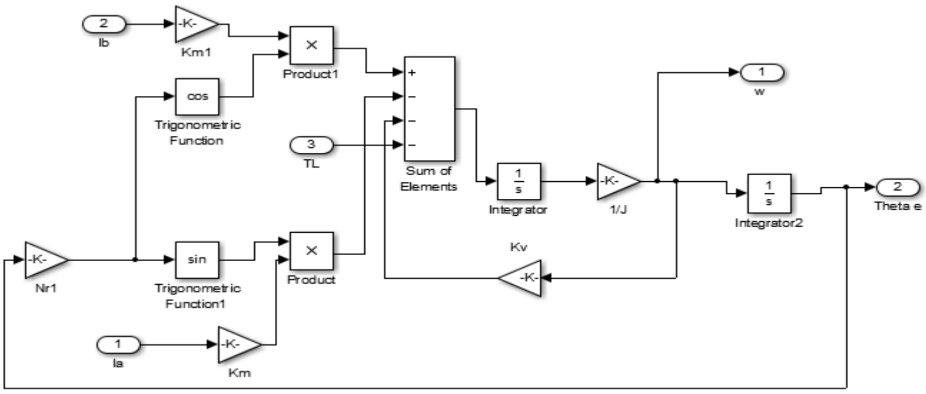

Fig 2: Subsystem of Speed and Position

III. SIMULATION AND RESULTS

Two sinusoidal inputs phase shifted by 90^0 is given as input to a PWM generator. The PWM pulses are given to the H-bridge which drives the hybrid stepper motor. Overall simulation diagram of microstepping operation of hybrid stepper motor is shown in Fig 3. Each phase is driven by a H-bridge connected to a 24V DC voltage source [6]. H bridge is built with four MOSFETs as shown in Fig 4. MOSFET s 1 and 3 are simultaneously turned on and off to get a positive voltage. MOSFETs 2 and 4 are switched simultaneously to get a negative voltage across the terminals. Fig 5 and Fig 6 shows the current and voltage waveforms of the two phases respectively. Speed and position waveforms are given in Fig 7 and Fig 8 respectively.

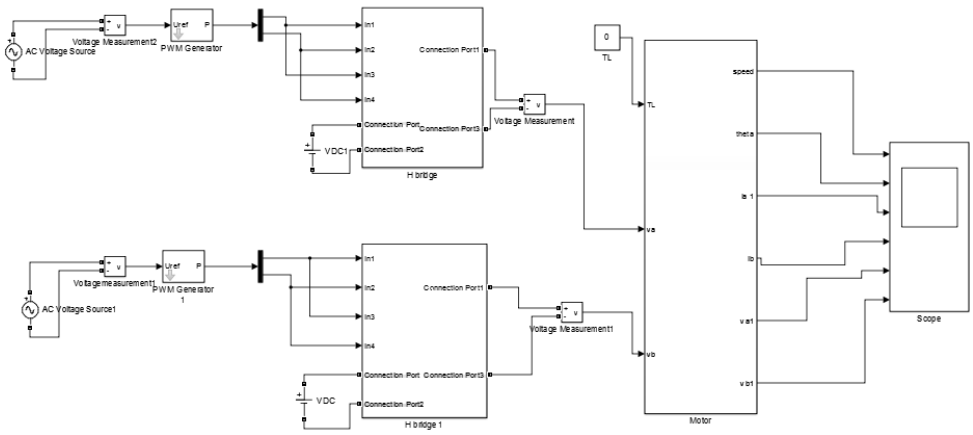

Fig 3: Overall Simulation Diagram of Hybrid Stepper Motor

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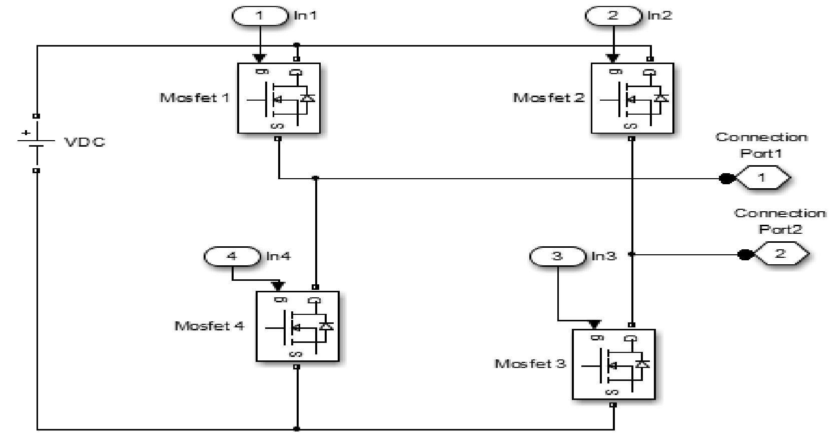

Fig 4: H-Bridge

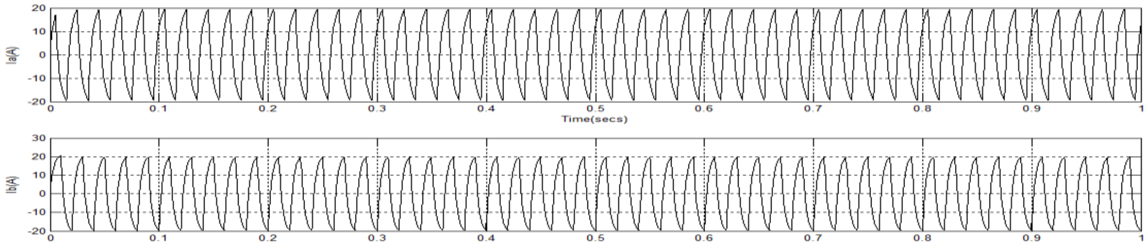

Fig 5: Phase Currents

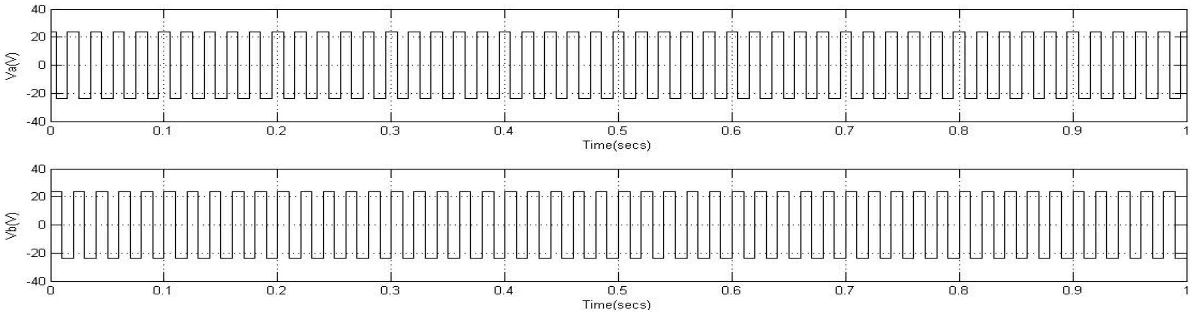

Fig 6: Phase Voltages

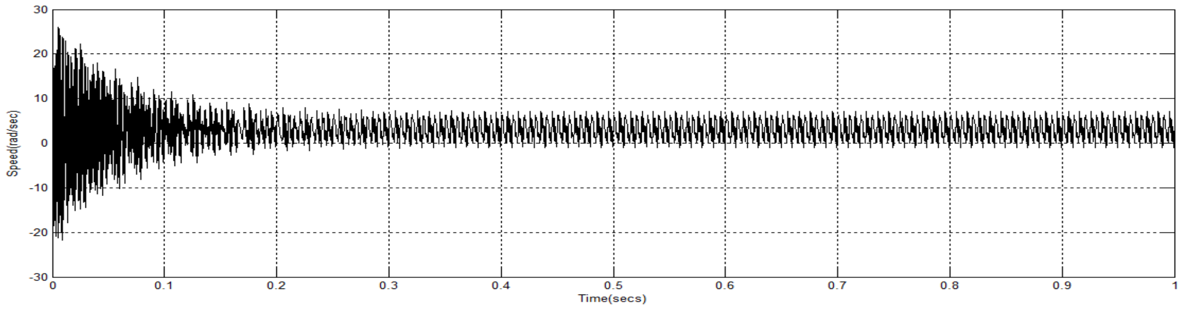

Fig 7: Speed Waveform

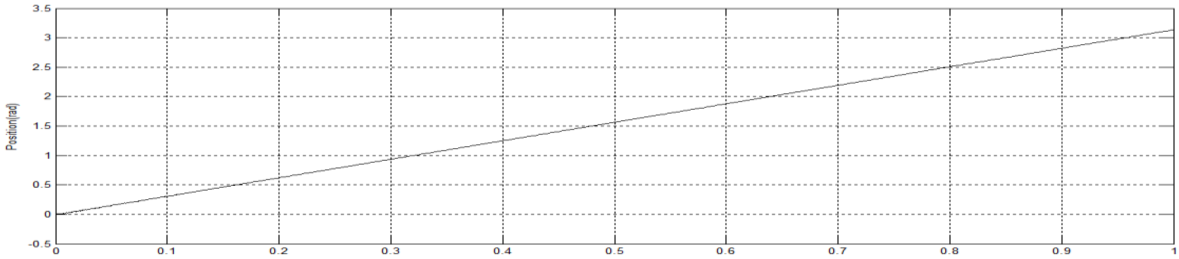

Fig 8: Position Waveform

IV. CONCLUSION

The modelling of a two phase hybrid stepper motor was implemented in MATLAB-SIMULINK. The modelled motor was driven in open loop microstepping mode. From the simulation results it can be seen that the voltage waveforms of the two phases are 90^0 displaced. Current waveforms of two phases are similar to sine and cosine waveforms. They are displaced by 90^0. Speed and position waveforms also agree well with the theoretical predictions. The drawback of the technique is that the microstepping drivers are costly and the current in the two phases should be simultaneously varied.

REFERENCES

[1]. T. Kenjo, Stepping Motors and Microprocessor Control (London: Oxford Clarendon Press, 1983).

[2]. D.Shin, W.Kim,Y.Lee and C.C.Chung, Phase compensated microstepping for permanent magnet stepper motors, IEEE Trans.Industrial Electronics, vol. 60, no. 12, pp. 5773-5780, 2013.

[3]. B.S. Somesh, A.Mukherjee, S.Sen, P.Karmakar, Constant Current Control of Stepper Motor in Microstepping Mode using PIC16F877A, Devices, Circuits and Systems (ICDCS), 2014, 2nd International Conference, 2014, pp.1-4.

[4]. W.Kim, D. Shin, C.C. Chung, Microstepping With Nonlinear Torque Modulation for Permanent Magnet Stepper Motors, IEEE Trans. Control Systems Technology, vol. 21, no. 5, pp. 1971-1979, 2013.

[5]. M. Bendjedia, Y. Ait-Amirat, B. Walther,A. Berthon, Position Control of a Sensorless Stepper Motor, IEEE Trans. Power Electronics, vol. 27, no. 2, pp. 578-587,2012.

[6]. Hoang Le-Huy, Brunelle P, Sybille G, Design and Implementation of a Versatile Stepper Motor Model for Simulink's SimPowerSystems, IEEE International Symposium on Industrial Electronics, 2008, ISIE 2008, pp-437-442.