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Simulation of Stepper Motor using Quasi Square Wave Input

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***Abstract*—Stepper motor is an electromechanical device which converts digital pulses into equivalent mechanical motions. The step motors have advantages like high torque development at low speed and it can start, stop and reverse the direction of travel at high speeds without any loss of steps. In this paper a two phase hybrid stepper motor(HSM) is modeled in matlab/simulink and a quasi square wave is generated and is provided as supply voltage for the two phases. Quasi square wave is generated using H bridge voltage source inverter.**

Key words- Hybrid stepper motor; quasi square wave; H Bridge.

I. INTRODUCTION

Stepper motors have a central gear-shaped iron piece surrounded by multiple toothed electromagnets. An external driver is required to energize the electromagnets. The working is as follows: first, power is given to one of the electromagnet and it attracts the gear's teeth magnetically towards it.When the next electromagnet is powered, the first one is turned off and the gear rotates to align with the next one and this process continues. This is how the motor shaft turns and each of these rotations are known as a step.

There are three basic types of stepper motors: Permanent magnet(PM), Hybrid and Variable reluctance(VR) stepper motor.Permanent magnet motors have a permanent magnet as the rotor and electromagnets as stator. They operate based on the attraction or repulsion between the rotor and the stator. In variable reluctance motors, a plain iron is used as rotor and they operate in such a way, so that minimum reluctance occurs with minimum gap, and the rotor points are attracted toward the stator magnet poles. Hybrid stepper motors are a combination of PM and VR motors and have maximum power in a small package size.

Positioning systems are powered by different types of electric motors. A special category of electric motors, which areincreasingly used in systems, are hybrid stepper motor. Due the simplicityof construction, command and control, they are used even inother electric drive systems.[1]

Most popular HSM are composed of a stator and two rotors. The motor stator has two control windings, each is placed on two diametrically opposed stator poles. Rotors are spaced axially by a permanent magnet at the periphery, which shows teeth uniform distributed and the first rotor is radially shifted with on tooth [3]

The organization of this paper can be summarized as follows. The Mathematical model of hybrid stepper motor is explained in Section II. The method by which the quasi square wave input is generated is explained in Section III. The overall system showing the stepper motor supplied with quasi square wave input is included in Section IV.The various simulation results are shown in Section V. Conclusion based on the experimental work is given in Section VI.

II. MATHEMATICAL MODEL OF HSM

The mathematical model of Stepper motor used is shown below:

$$\frac{di_a}{dt} = \frac{1}{L_a}[U_a - R_a i_a + k_m \omega \sin(N_R\theta)]$$

$$\frac{di_b}{dt} = \frac{1}{L_b}[U_b - R_b i_b - k_m \omega \cos(N_R\theta)]$$

$$\frac{d\omega}{dt} = \frac{1}{J}[-k_m i_a \sin(N_R\theta) + k_m i_b \cos(N_R\theta) - B\omega - k_D \sin(4N_R\theta) - M_R]$$

$$\frac{d\theta}{dt} = \omega \qquad (1)$$

where:
i_a& i_b= currents in phase A and B(Amperes),
U_a& U_b= phase voltages (Volt),
R_a,& R_b = phase resistances(ohm),
L_a& L_b=phase inductances(Henry),
k_m = motor torque constant(Nm/A),
ω = rotor speed(rad/sec),
N_R = number of rotor teeth,
θ = rotor position(radians),
J = rotor inertia(kgm^2),
B = viscous friction constant(Nm/rad/sec),
M_R = load torque

The term $k_D\sin(4N_R\theta)$ represents the detent torque due to permanent rotor magnet interacting with the magnetic material of the stator poles. Detent torque is the torque required to rotate a non-energized stepper motor.This torque will exist even if the phase current is zero. Typically k_D is 5 to 10 percent of the value of $k_m i_o$, where i_o is the rated current[2].

The block diagram of the mathematical model described in (1) implemented in Matlab/Simulink is presented in Figure 1.

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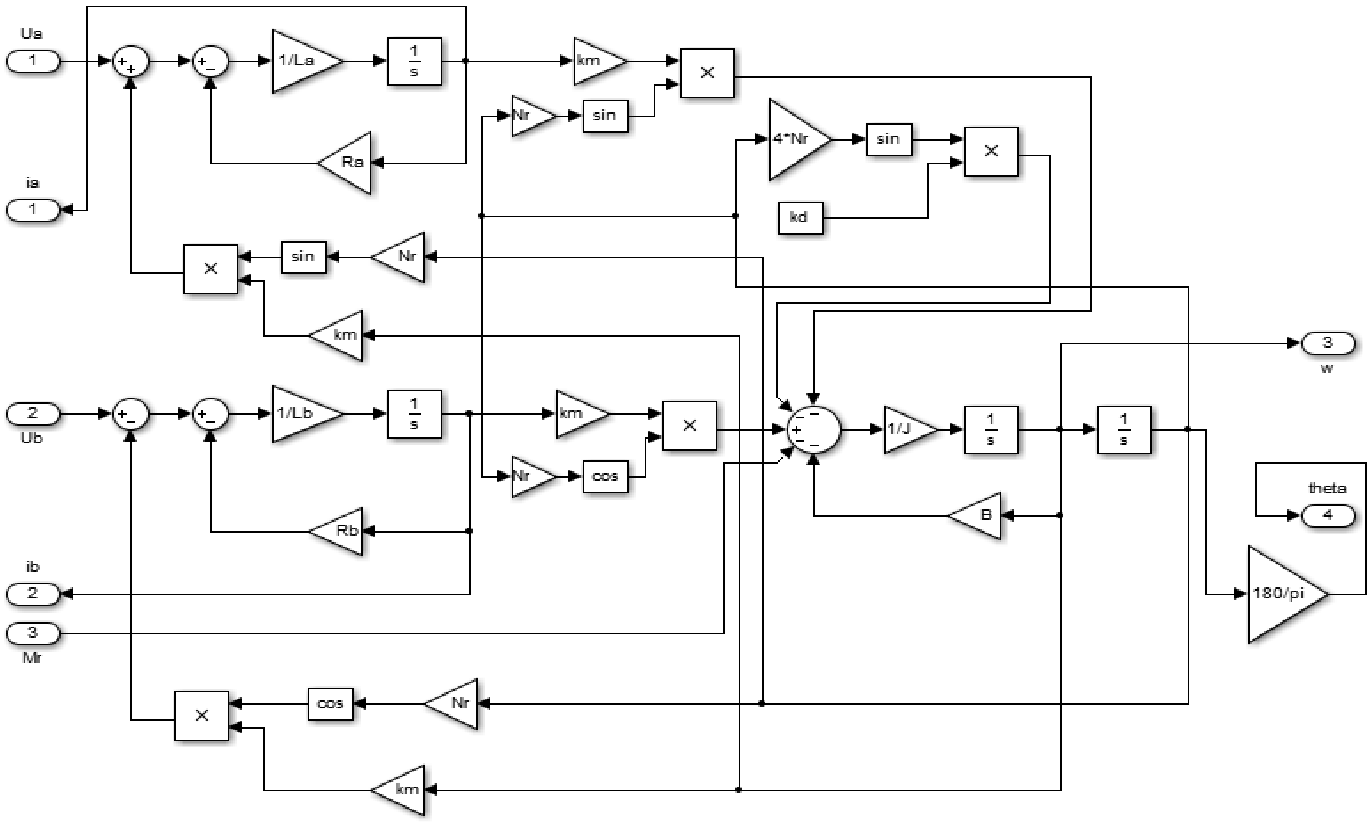

Fig.1. Matlab/simulink model of stepper motor

III. QUASI SQUARE WAVE GENERATION

Modified sine wave or also known as quasi square wave is given as input to the stepper motor. The Matlab/simulink set up to generate quasi square wave is shown in figure 2.

It uses an H-bridge bipolar voltage source inverter. The gate pulses used to generate quasi square wave is shown in figure 3.

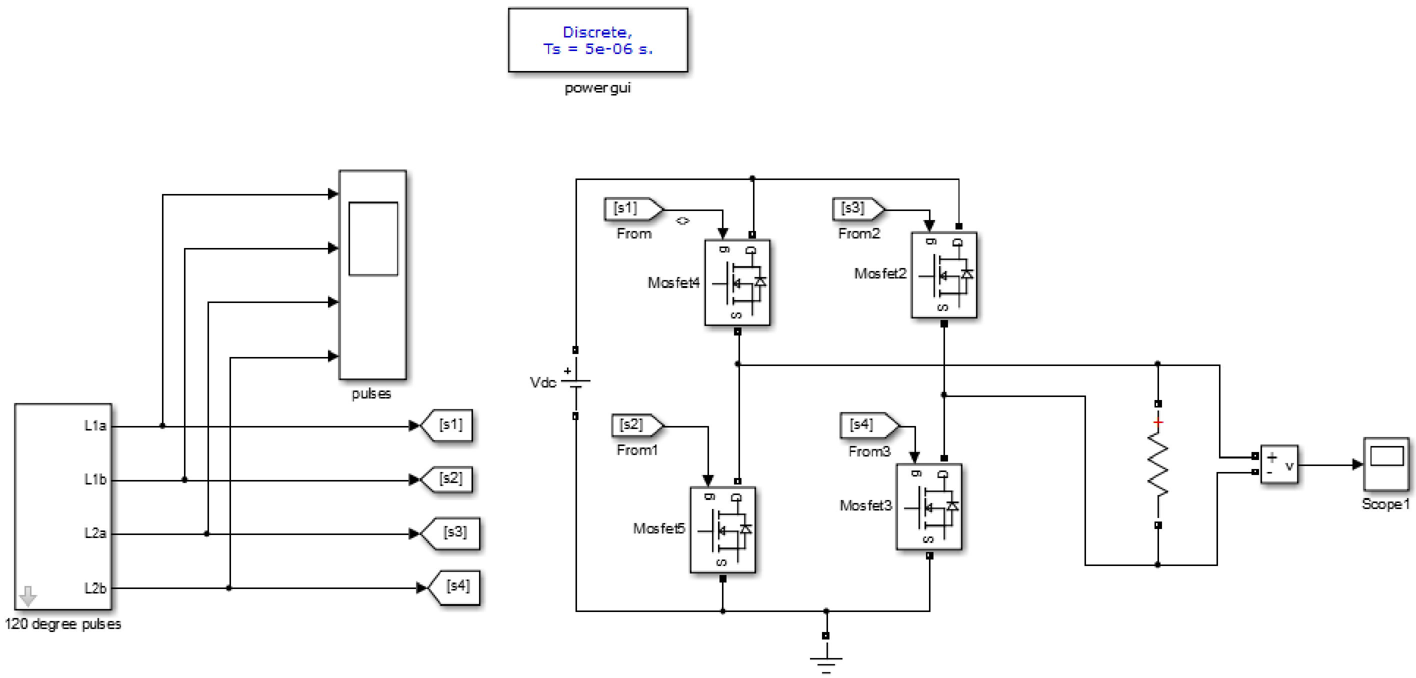

Fig.2. H-bridge bipolar voltage source inverter for quasi square wave generation.

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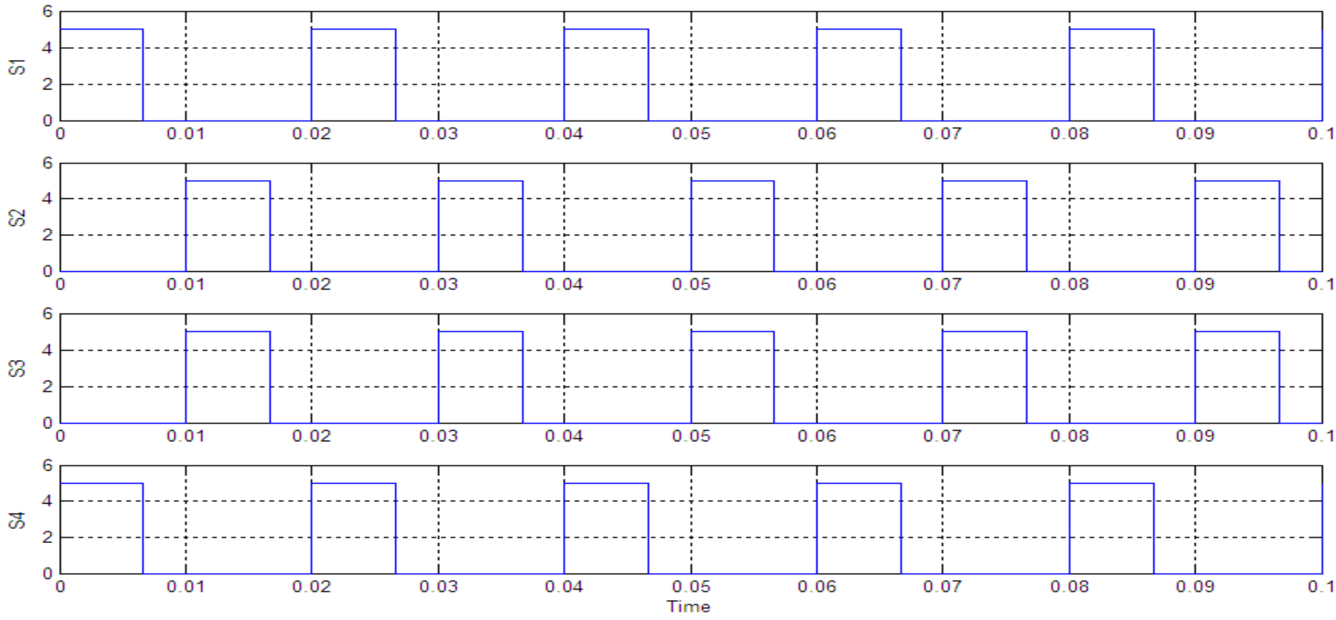

Fig.3. Gate pulses for the inverter

The gate pulses S1&S4 and S2&S3 are the same. Also S2 pulse is 120^0 out of phase with that of S1 and this helps to provide a dead time, ie., there is some time where all the MOSFETs are OFF. Initially S1 and S4 will be ON. After turning off S1&S4 and before turning on S2&S3 there will some dead time where noMOSFETs are ON.

The output from the inverter is a quasi square wave which is provided as input to one phase A of the stepper motor. The supply voltage to phase A is denoted as U_a. The supply voltage to phase B, U_b is the inverted version of U_a or in other words it is 180^0 out of phase with U_a. The modified sine wave inputs U_a and U_b is shown in Fig.4

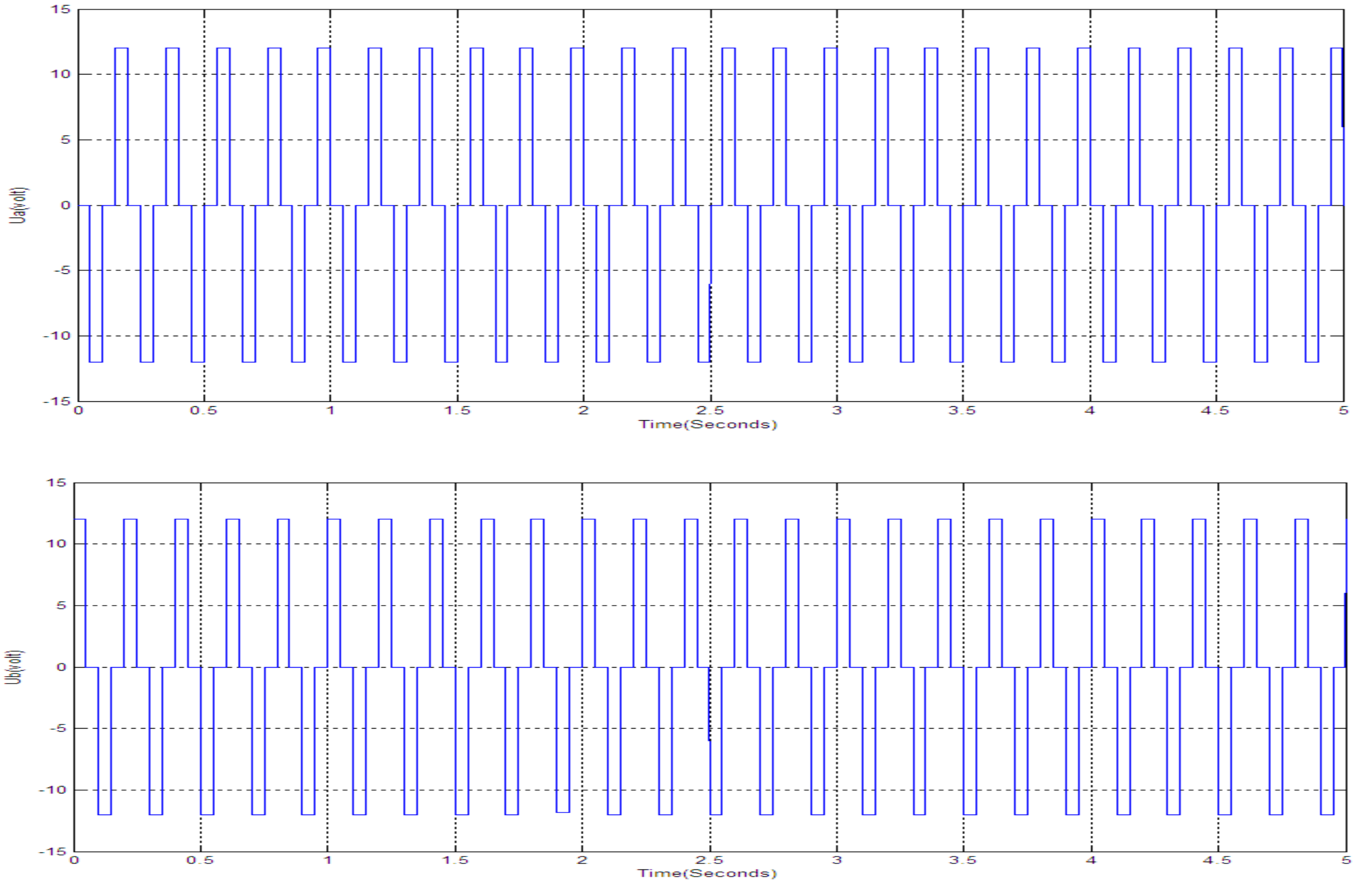

Fig. 4 Quasi Square wave input for phase A&B

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stepper motor system. Both of the subsystem has been explained in the previous two sections(Section II & III).

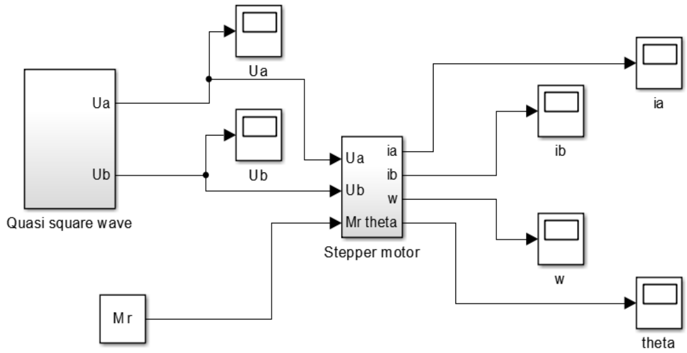

Fig.5. Overall system for simulation

The input to stepper motor are U_a, U_b and M_R. Ua and Ub are the quasi square wave inputs and Mr is the load torque which is a constant value. The outputs are two phase currents ia & ib, rotor angular velocity, ω and rotor position,θ.

V. SIMULATION RESULT

The various parameter values used for simulations are V_{dc} = 12V, $L_a = L_b$ = 12mH, $R_a = R_b = 11\Omega$, B = 0.025 Nm/rad/s, N_R = 50, J = 1.125*10^{-4} kgm^2, k_m = 0.22 Nm/A, M_r = 0.07, k_d = 0.022 Nm[1].

The various simulation results are shown in the following figures. Figure 6&7 shows the phase current waveforms. On examining phase current waveform we can see that it is almost same as the supply voltage waveform. The current in phase B is 180^0 out of phase with that of current in phase A, similar to phase A&B voltages.

The variation of speed of motor is illustrated in figure 8. Motor speed varies uniformly in each step. Initially speed increases from zero and reaches a maximum value, then speed decreases and settles to zero when it attains steady state, this constitutes one step.

The complete 360^0 rotation of rotor in shown in figure 9. The angle of rotation increases in each step.

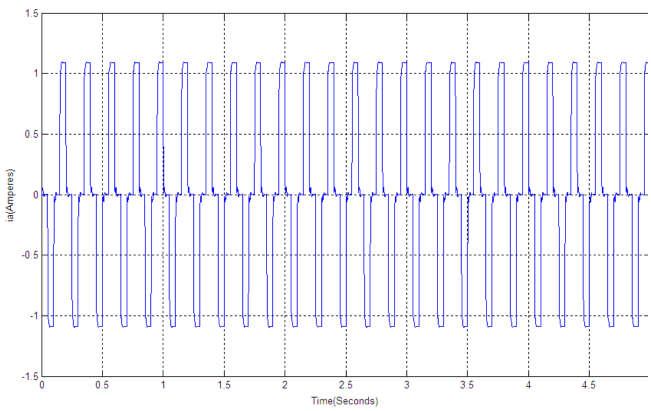

Fig.6. Current in phase A

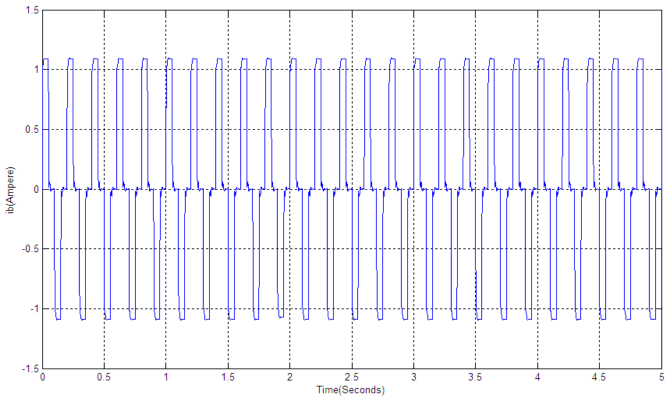

Fig.7. Current in phase B

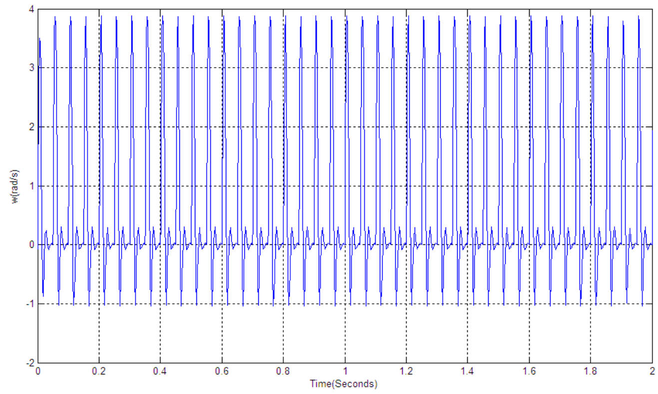

Fig.8. Angular velocity of the motor

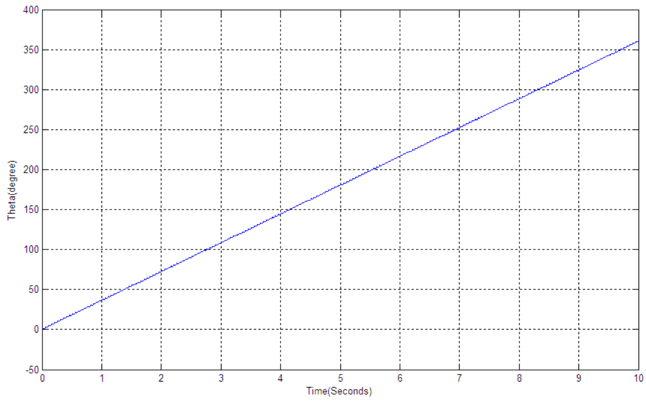

Fig.9. Variation of theta

IV. CONCLUSION

This paper presents the simulation of stepper motor using quasi square wave input. A two phase hybrid stepper motor is modeled in matlab/simulink and a quasi square wave is generated and is provided as supply voltage for the two phases. Quasi square wave or modified sine wave is generated using H bridge voltage source inverter. The generated quasi square is provided as input to phase A and the inverted version is applied to phase B. The simulation results obtained were satisfactory.

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