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Analysis of Speed Control of Three Phase Induction Motor by V/f Method Using SVPWM Technique

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Abstract- **This paper deals with "Analysis of speed control of three phase induction motor by V/f Method using SVPWM Techniques". Induction motor is widely used in industrial plant because we can easily control the speed of the motor by using different techniques. There are so many techniques for the speed control of induction motor like voltage control method, pole changing arrangement, cascade control, V/f method. Rotor resistance control method is used for slip ring induction motor. In V/f Method ac supply is rectified & then applied to a PWM inverter to obtain a variable voltage and variable frequency. By this method we can get different synchronous speed with almost same maximum torque. Thus, the motor is completely utilized & also we have a good range of speed control. BY using SVPWM techniques output voltage obtain will be more than the output voltage obtain by SPWM technique that's why we are this technique & efficiency of the motor is also improved it means it is more efficient above 90% at full load.THD in the line voltage & line current is also less. This technique is used for speed control of induction motor is used for both constant and fan type load. By using this technique induction motor replace the separately excited dc motor because dc motor takes time to time maintenance for commutator and brush holder. Due to which cost of the drive system is increases. A 4.4kW squirrel cage induction motor is used for analysis purpose. Simulation results are obtained.**

Keywords* – *SVPWM inverter, PIController, Induction motor

I. INTRODUCTION

Three phase induction motors are the most commonly used a.c. motors in the industry because they have simple and rugged construction, low cost, high efficiency, reasonable good power factor, self starting torque and low maintenance. Almost more than 90% mechanical power used in industry is provided by three phase induction motors. For change the drive speed as desired by the process to maintain different process parameter at different load. Speed control of the motor is necessary. The necessary conditions for developing proper induction motor drives are –The decreasing cost & improved performance in power electronics switching devices. The possibility of implementing complex algorithm in the new microprocessor. However, one precondition had to made for the development of suitable method for the speed control of induction motor, because in contrast to its mechanical simplicity their complexity regarding their mathematical structure (multivariable& non-linear) is not a trivial matter. Now a day's variable frequency drive has wide scope in industries due to the following reason- Speed control, Energy saving, Easy control &cost optimization. These drives are made by using power converter topologies & control scheme. Previous methods for speed control of three phase induction motor have certain disadvantage. By using the power converter output quality is improved but at the same time switching losses is increased due to which cost increases. By using different PWM technique different switching pattern is achieved. Step by step implementation of SVPWM for induction motor control to improve the efficiency of the variable frequency drives. It's main characteristics is the good performance & result obtain by this method is good as the result obtain by other method.

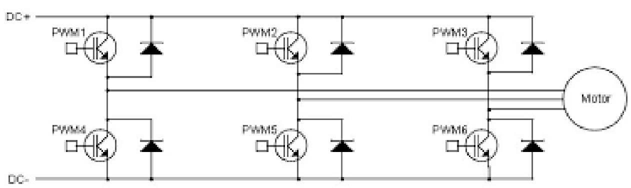
II. NOMENCLATURE

Ψqs – quadrature axis stator flux linkage
Ψds – direct axis stator flux linkage
Ψqr – quadrature axis rotor flux linkage
Ψqs – direct axis rotor flux linkage
ψ_{mq} – quadrature axis mutual flux linkage
ω – rotor speed
ψ_{md} – direct axis mutual flux linkage
X_{ml} – leakage mutual reactance
X_m – mutual reactance
X_{ls} – leakage stator reactance
X_{lr} – leakage rotor reactance
R_S – stator resistance
R_r – rotor resistance
V_{qs} – quadrature axis stator voltage
V_{ds} – direct axis stator voltage
V_{qr} – quadrature axis rotor voltage
V_{dr} – direct axis rotor voltage
I_{qs} – quadrature axis stator current

I_{ds} - direct axis stator current
I_{qr} – quadrature axis rotor current
I_{dr} – direct axis rotor current
T_e – electromagnetic torque
p – no of poles
J – moment of inertia
T_l – load torque
B – friction coefficient.

III. COMPONENTS USED IN THE MODEL OF SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

A. SVPWM –



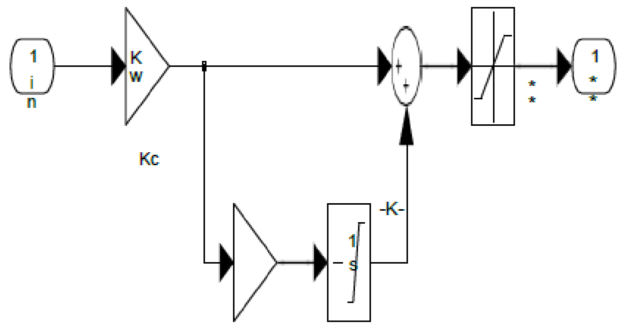
There are eight possible combination of on and off states of the given switches. In this diagram the phase difference between the same leg transistor (switch) is 180 degree and phase difference between the upper group transistor and the lower group transistor is 120 degree.Switch of the same leg is not On at the same time. These combinations and resulting instantaneous output line-to-line and phase voltage for a dc bus voltage of V_{DC} are shown in table-I

c	b	a	V_{AN}	V_{BN}	V_{CN}	V_{AB}	V_{BC}	V_{CA}
0	0	0	0	0	0	0	0	0
0	0	1	$2V_{DC}/3$	$-V_{DC}/3$	$-V_{DC}/3$	V_{DC}	0	$-V_{DC}$
0	1	0	$-V_{DC}/3$	$2V_{DC}/3$	$-V_{DC}/3$	$-V_{DC}$	V_{DC}	0
0	1	1	$V_{DC}/3$	$V_{DC}/3$	$-2V_{DC}/3$	0	V_{DC}	$-V_{DC}$
1	0	0	$-V_{DC}/3$	$-V_{DC}/3$	$2V_{DC}/3$	0	$-V_{DC}$	V_{DC}
1	0	1	$V_{DC}/3$	$-2V_{DC}/3$	$V_{DC}/3$	V_{DC}	$-V_{DC}$	0
1	1	0	$2V_{DC}/3$	$V_{DC}/3$	$V_{DC}/3$	$-V_{DC}$	0	V_{DC}
1	1	1	0	0	0	0	0	0

B. PI Controller –

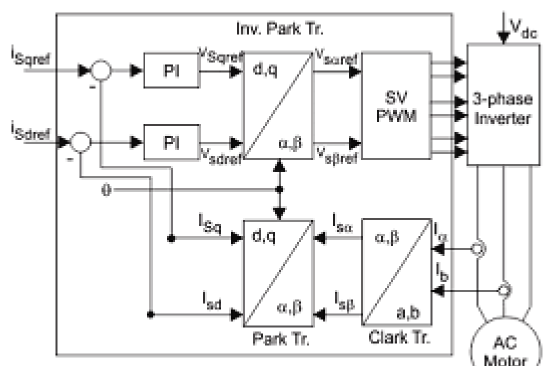
Correction factor is also used in pi controller for improving accuracy of the system. Stability of PI Controller is done by Ziegler Nichols method. It is used to increase the speed response & also eliminate steady state error .Other advantage of the PI Controller is that the order of the system is increases , damping improved , reduced maximum overshoot, decrease bandwidth and increased the rise time.

$$U(t) = Kpe(t) + Ki \int e(t)\, dt$$



IV. MODELLING OF INDUCTION MOTOR

$d\psi_{qs}/dt = \omega_s [\, V_{qs} - \omega_r/\omega_s \psi_{ds} + R_s/X_{ls} (\psi_{mq} - \psi_{qs})\,]$
$d\psi_{ds}/dt = \omega_s [\, V_{ds} + \omega_r/\omega_s \psi_{qs} + R_s/X_{ls} (\psi_{md} - \psi_{ds})\,]$
$d\psi_{qr}/dt = \omega_s [\, V_{qr} - (\omega_r - \omega)/\omega_s \psi_{dr} + R_r/X_{lr} (\psi_{mq} - \psi_{qr})\,]$
$d\psi_{qs}/dt = \omega_s [\, V_{dr} + (\omega_r - \omega)/\omega_s \psi_{qr} + R_r/X_{lr} (\psi_{md} - \psi_{dr})\,]$
where, $\psi_{mq} = X_{ml} [\psi_{qs}/X_{ls} + \psi_{qr}/X_{lr}]$
$\psi_{md} = X_{ml} [\psi_{ds}/X_{ls} + \psi_{dr}/X_{lr}]$
$X_{ml} = 1/(1/X_m + 1/X_{ls} + 1/X_{lr})$
Substitute the value of flux linkage and find the current
$I_{qs} = 1/X_{ls} (\psi_{qs} - \psi_{mq})$
$I_{ds} = 1/X_{ls} (-\psi_{md} + \psi_{ds})$
$I_{qr} = 1/X_{lr} (-\psi_{mq} + \psi_{qr})$
$I_{dr} = 1/X_{ls} (-\psi_{md} + \psi_{dr})$
Torque equation
$T_e = 3/2\,(p/2)\, 1/\omega_s (\psi_{ds} I_{ds} - \psi_{qs} I_{ds})$
$\omega = \int p/2J\, (T_e - T_l)$
Using Clarke transformation
$V\alpha = 2/3 V_{AN} - 1/3 V_{BN} - 1/3 V_{CN}$
$V\beta = 1/(3)^{1/2} V_{BN} - 1/(3)^{1/2} V_{CN}$
With the help of park's transformation d &q component of line voltage and phase voltage
$V_d = \cos\theta\, V\alpha + \sin\theta\, V_\beta$
$V_q = -\sin\theta\, V_\alpha + \cos\theta\, V_\beta$



The motor speed is used as feedback signal in the controller. The controller calculates reference values of the two decoupled components of stator current space vector in the SRRF which are iqs and ids forthe control of torque and flux respectively. The two components of the currents are transformed into three phase currents which are IAS, IBS, ICS in the stationary reference frame of reference. Now as a balanced load, two of the phase currents are sensed and the third one is calculated from the two sensed currents. The current controller controls the reference currents close to sensed three phase currents in the stationary reference frame and operates the voltage source inverter to feed three phase induction motor. This ensures a high level of performance of the vector controlled induction motor (VCIMD).Because of the smooth, efficient and maintenance free operation of VCIMDs, such drives are finding increasing applications in many drive applications such as air conditioning, refrigeration, fans blowers, pumps, waste water treatment plants ,elevators, lifts traction motors, electric vehicles, etc.

TABLE I. SWITCHING PATTERN ,CORRESPONDING SPACE VECTORS AND THEIR (VA , VB) COMPONENTS

C	b	a	V_α	V_β
0	0	0	0	0
0	0	1	$2/3V_{DC}$	0
0	1	0	$-V_{DC}/3$	$V_{DC}/(3)^{1/2}$
0	1	1	$V_{DC}/3$	$V_{DC}/(3)^{1/2}$
1	0	0	$-V_{DC}/3$	$-V_{DC}/(3)^{1/2}$
1	0	1	$V_{DC}/3$	$-V_{DC}/(3)^{1/2}$
1	1	0	$-2/3V_{DC}$	0
1	1	1	0	0

V. MECHANISM OF SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

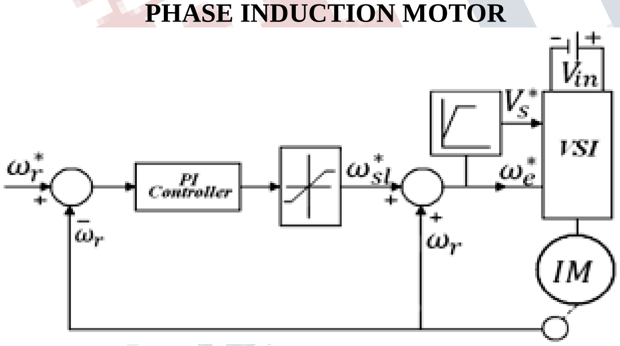
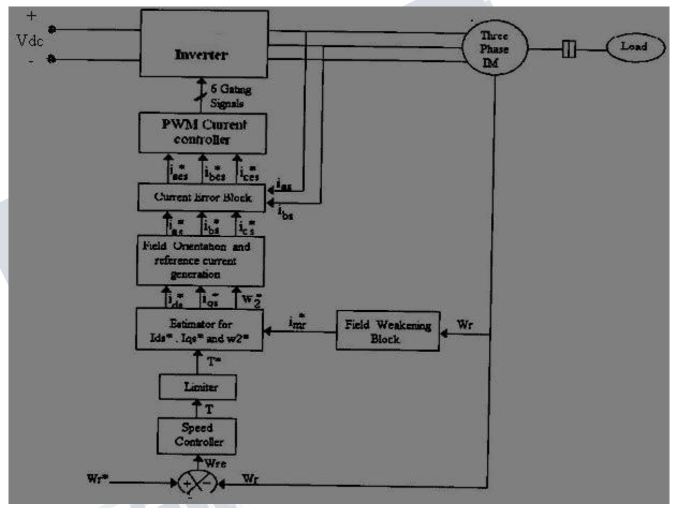


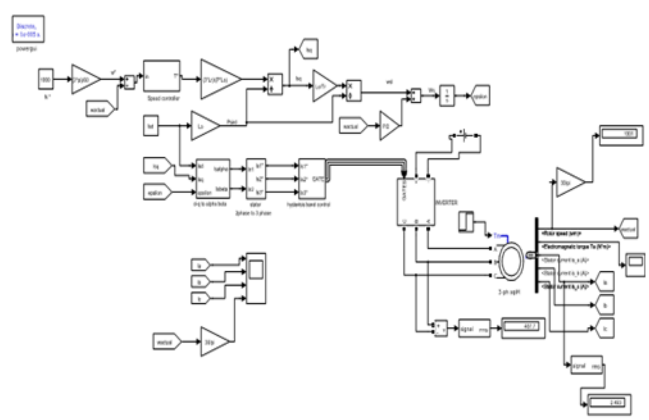
Fig. 1. Block diagram of closed loop of speed control of induction motor

It includes inner speed loop with slip limiter and outer speed loop. For a given value of stator current slip speed has fixed value, the slip speed loop is also work as a inner current loop. The motor operate in between synchronous speed and the speed at which torque will be maximum with different frequencies. It should be ensure that torque to current ratio will be high. The machines operate in four quadrants. This figure shows that the measured speed is compared with the set reference speed in the error detector and the resulting output is known as speed error is processed in the speed controller. The synchronous speed is obtain by adding actual speed and speed error, set the inverter frequency. The reference signal for the closed loop control of the motor terminal voltage is generated at inverter frequency. It ensure that the flux should be constant at based speed and above the base speed at constant terminal voltage. The command input may be positive or negative depending upon the set reference speed and the motor shaft speed. The speed error (e □) is processesed in the speed controller which may be of different types depending upon the required dynamic performance of the drive. And accordingly the controller is used.

V. FLOW CHART OF SPEED CONTROL OF THREE PHASE INDUCTION MOTOR



VI. SIMULATION DIAGRAM OF SPEED CONTROL OF THREE PHASE INDUCTION MOTOR USING V/F METHOD USING SVPWM TECHNIQUE



VII. RESULTS

Simulation on 4.4KW induction motor having data of –
Vs rated = 415, Is rated = 7.2, f = 50
P = 4, Rs = 1.557, Rr = 2.62,Ls =

195e-3, Lr = 195e-3, Lo = 177e-3, Lls = Ls-Lo = 18e-3, Llr = Lr-Lo = 18e-3, J = 0.1,B = 0.0161

Case-1 When refrence speed is set as 1443rpm

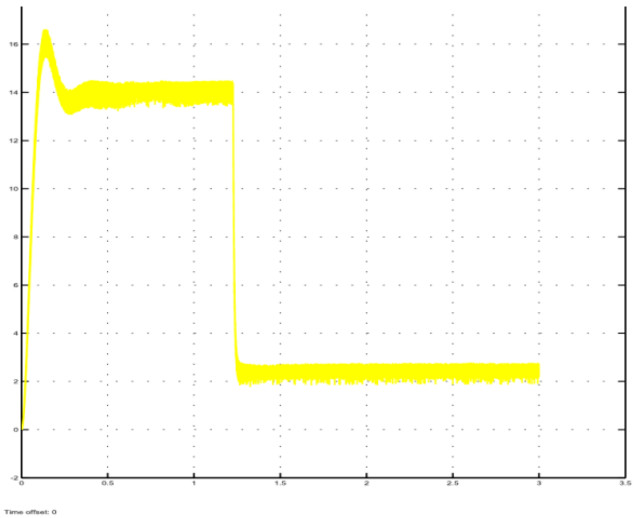


Fig. 2. Graph between torque versus time

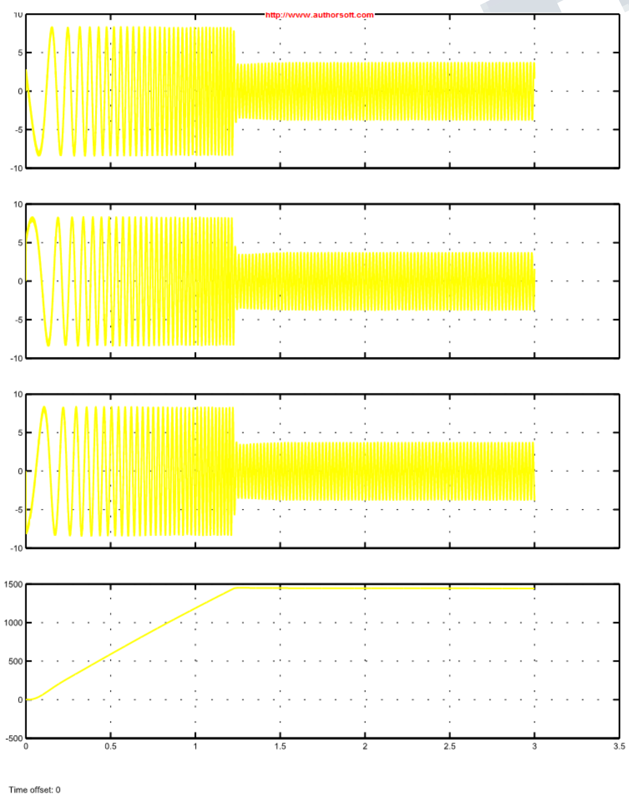


Fig. 3. Graph between stator current (ia,ib,ic) versus time and speed versus time

Case2-When applied load torque is 75% of rated torque

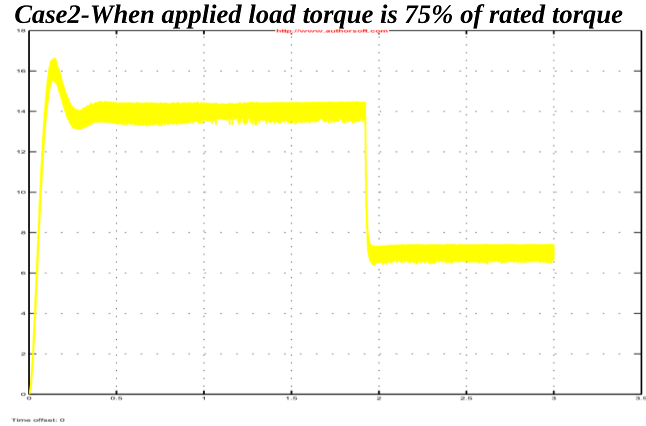


Fig. 4. Graph between torque versus time

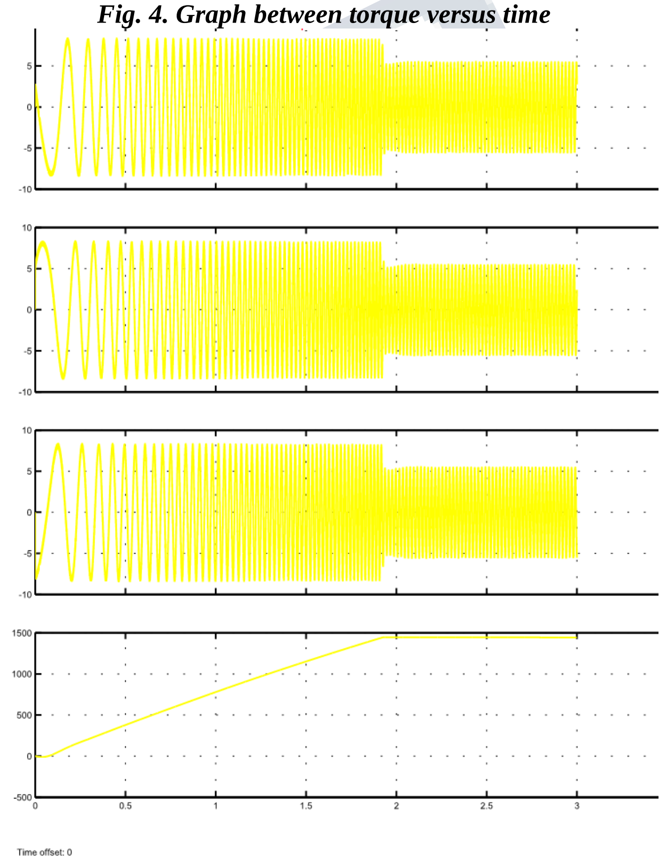


Fig. 5. Graph between stator current (ia,ib,ic) versus time and speed versus time

Case3- When moment of inertia is increase 5 times and friction coefficient is increases 2 times

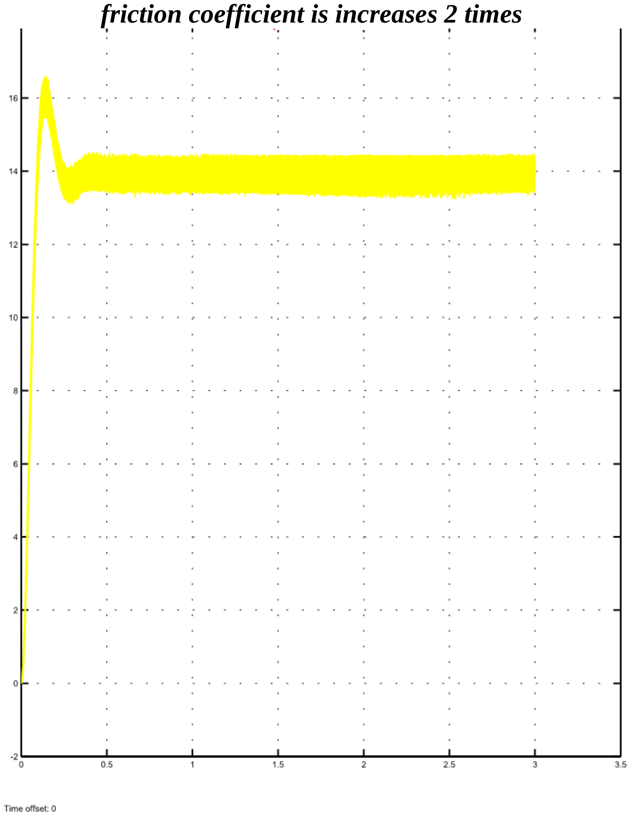


Fig. 6. Graph between torque versus time

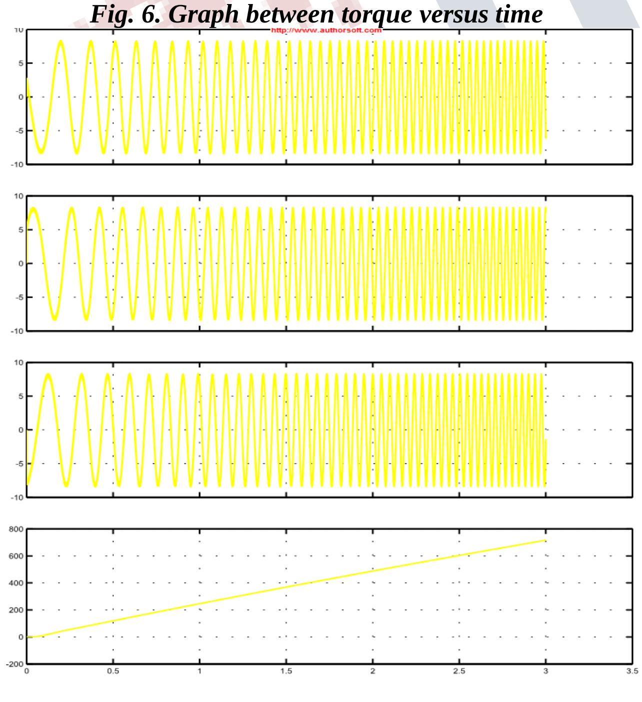


Fig. 7. Graph between stator current (ia,ib,ic) versus time and speed versus time

VIII. CONCLUSION

From the above result obtain by this scheme it is conclude that the dynamic response of torque is obtain by this method is better than the other controlling scheme in terms of rise time, settling time .These techniques have several other advantages it means flux sensor is absent due to which cost and complexity of the drive is reduced and drift problem is not arise.

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