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Efficient Harmonics Reduction Based Three Phase H Bridge Speed Controller for DC Motor Speed Control using Hysteresis Controlled Synchronized Pulse Generator

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ABSTRACT: The DC Motor is the most commonly used actuator for producing continuous movement whose speed of rotation can easily be controlled, making them ideal for use in applications where speed control, servo type control, and/or positioning is required. In many applications, DC motor is required to be rotated in clockwise and counter clockwise directions. For this purpose H Bridge is designed. H-Bridge circuits are popular circuit for Direct Current (DC) Motor and make it turn. It's called H- Bridge because it looks like the capital "H" on classical schematics. The ability of H-bridge circuit is that motor can be driven forward or backward at any speed.

Although lots of work has been done on development of H-bridge controller for electrical drives but during analysis it has been found that, during direction change of electrical drives using H-bridge controller drive suffers from oscillations in the steady state. Different strategies are available for the speed regulation of electrical drives but cannot able to provide efficient regulation in case of H-bridge controller.

The main cause behind this deficiency, found during analysis is the harmonics presented in the armature current. This paper presents a technique for efficient harmonics reduction based three arms H-bridge speed controller for DC motor speed control using Hysteresis Controlled Synchronized Pulse Generator (HCSPG) technique. This paper first presents the development of Hysteresis Controlled Synchronized Pulse Generator (HCSPG) technique for three phase operation using Matlab Simulink, which then interfaced with the three arms H bridge controlled DC motor using the Matlab Simulink. The speed of DC motor is controlled through the controlling of firing angles of power semiconductor switch using HCPPG. The proposed techniques basically deals with the generation of controlled voltage for three arms H bridge followed by HCSPG which generates controlled pulses with reference to speed obtained at the output for firing. The model developed uses controlled pulses generated by HCSPG hence shows the ability to provide high harmonics reduction efficiency. We also concluded that the proposed controller will achieve the shorter settling time and also lower overshoot and steady state error.

KEYWORDS: DC motor speed control, Hysteresis Controlled Synchronized Pulse Generator, Three arms H-bridge speed controller, Harmonics reduction.

I. INTRODUCTION

The mechatronic systems, robots and low to medium power machine-tools often use DC motors to drive their work loads. These motors are commonly used to provide rotary (or linear) motion to a variety of electromechanical devices and servo systems. There are several well known methods to control DC motors such as: Proportional-Integral PI, Proportional-Integral-Derivative PID [1]. Despite a lot of researches and the huge number of different solutions proposed, most industrial control systems are based on conventional PID controllers. In addition to these controllers H bridge controller are also widely used to control the speed of DC motors.

All above controllers are external speed control which controls the following parameters of the motor.

i. Speed control of DC motor using Armature voltage control.
ii. Speed control of DC motor using Field Control.
iii. Speed control of DC motor using Armature Current control.

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Most of time it is found that, speed control by controlling one of the above parameters will not able to provide high regulation, because of the fluctuations present n the controlled parameters known as Harmonics. Therefore by reducing the harmonics present in controlled parameters a highly efficient speed control can be obtained.

This paper presents a method for Efficient Harmonics Reduction in Armature current controlled Based Three Phase H Bridge Speed Controller for DC Motor Speed Control using Hysteresis Controlled Synchronized Pulse Generator.

II.DC MOTOR

Almost every mechanical movement that we see around us is accomplished by an electric motor. Electric machines are a means of converting energy. Motors take electrical energy and produce mechanical energy. Electric motors are used to power hundreds of devices we use in everyday life. Motors come in various sizes. Huge motors that can take loads of 1000's of Horsepower are typically used in the industry. Some examples of large motor applications include elevators, electric trains, hoists, and heavy metal rolling mills. Examples of small motor applications include motors used in automobiles, robots, hand power tools and food blenders. Micro-machines are electric machines with parts the size of red blood cells, and find many applications in medicine.

Electric motors are broadly classified into two different categories: DC (Direct Current) and AC (Alternating Current). Within these categories are numerous types, each offering unique abilities that suit them well for specific applications? In most cases, regardless of type, electric motors consist of a stator (stationary field) and a rotor (the rotating field or armature) and operate through the interaction of magnetic flux and electric current to produce rotational speed and torque. DC motors are distinguished by their ability to operate from direct current.

There are different kinds of D.C. motors, but they all work on the same principles. In this section, we will study their basic principle of operation and their characteristics.

II.I.DC MOTOR EQUIVALENT CIRCUIT

The schematic diagram for a DC motor is shown below. A DC motor has two distinct circuits: Field circuit and armature circuit. The input is electrical power and the output is mechanical power. In this equivalent circuit, the field winding is supplied from a separate DC voltage source of voltage V_f. R_f and L_f represent the resistance and inductance of the field winding. The current I_f produced in the winding establishes the magnetic field necessary for motor operation. In the armature (rotor) circuit, V_T is the voltage applied across the motor terminals, Ia is the current flowing in the armature circuit, Ra is the resistance of the armature winding, and E_b is the total voltage induced in the armature.

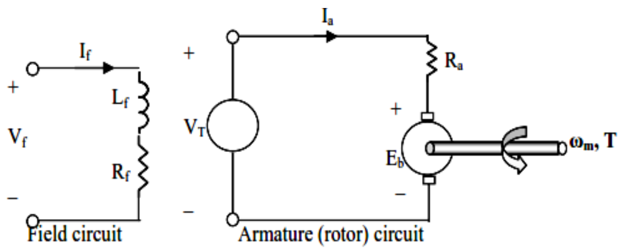

Fig.1 DC Motor representation

II.II. VOLTAGE EQUATION

Applying KVL in the armature circuit of Figure (1).

$$V_T = E_b + Ia\,Ra \quad \ldots(1)$$

Where V_T is voltage applied to the armature terminals of the motor and Ra is the resistance of the armature winding.

The induced voltage is typically represented by symbol e (or E) and the terminal voltage by v (or V). At standstill, the motor speed is zero; therefore back emf is also zero. The armature current at starting is thus very large.

Applying KVL in the field circuit of Figure (1)

$$V_f = R_f\, I_f \quad \ldots(2)$$

Where V_f is voltage applied to the field winding (to produce the magnetic field), R_f is the resistance of the field winding, and I_f is the current through the field winding.

II.III. DC MOTOR SPEED CONTROL

Many applications require the speed of a motor to be varied over a wide range. One of the most attractive features of DC motors in comparison with AC motors is the ease with which their speed can be varied.

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We know that the back emf for a separately excited DC motor:

$$E_b = K\, \Phi\, \omega_m = V_T - Ia\, Ra$$

Rearranging the terms,

Speed $\omega_m = (V_T - Ia\, Ra)/K\Phi$ …(3)

From this equation, it is evident that the speed can be varied by using any of the following methods:

- Armature voltage control (By varying V)
- Field Control (By Varying Φ)
- Armature Current control (By varying Ia)

III. SYNCHRONOUS 6-PULSE GENERATOR

The Synchronized 6-Pulse Generator block directly available in MATLAB Simulink (Shown in Figure (2)), can be used to fire the six thyristors of a six-pulse converter. The output of the block is a vector of six pulses individually synchronized on the six thyristor voltages. The pulses are generated alpha degrees after the increasing zero crossings of the thyristor commutation voltages.

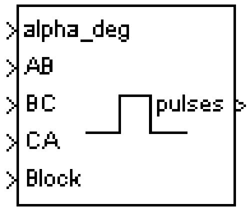

Fig.2 Synchronous 6 pulse generator block

Figure (3) displays the synchronization of the six pulses for an alpha angle of 0 degrees. The pulses are generated exactly at the zero crossings of the three line-to-line synchronization voltages.

The Synchronized 6-Pulse Generator block can be configured to work in double-pulsing mode. In this mode two pulses are sent to each thyristor: a first pulse when the alpha angle is reached, then a second pulse 60 degrees later, when the next thyristor is fired. Figure (4) display the synchronization of the six pulses for an alpha angle of 30 degrees and with double-pulsing mode. Notice that the pulses are generated 30 degrees after the zero crossings of the line-to-line.

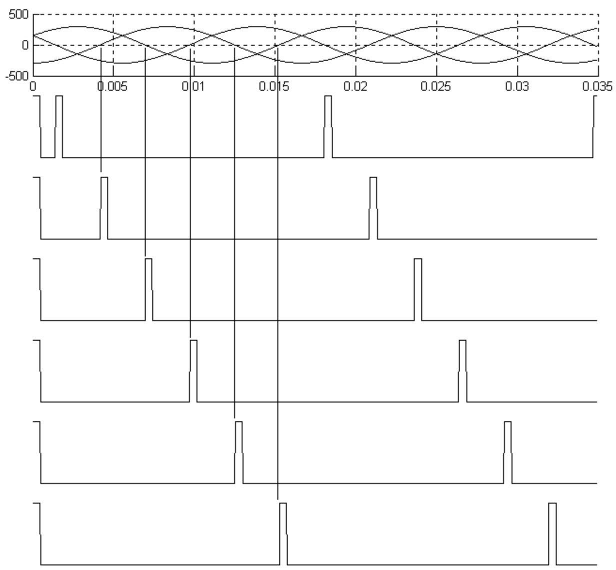

Fig.3 Synchronized 6 pulse generations.

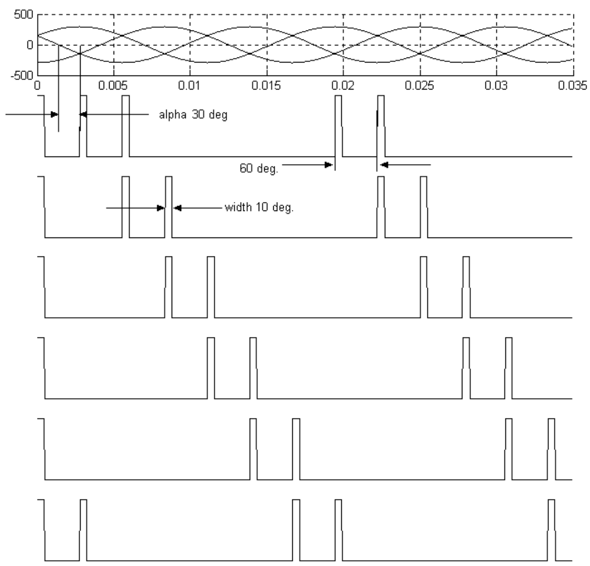

Fig.4 Synchronized 6 Double pulse generations.

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IV. METHODOLOGY

Earlier lots of work have been done for speed control of drives but this area is still lacking for an efficient and real time speed control. This paper basically deals with the reduction of harmonics of armature current using Hysteresis controlled synchronous pulse generator for Three Phase H Bridge controlled DC motor, which leads to the efficient solution of speed control of DC motor. This section briefly describes the proposed algorithm with help of bloc diagram shown in figure (5).

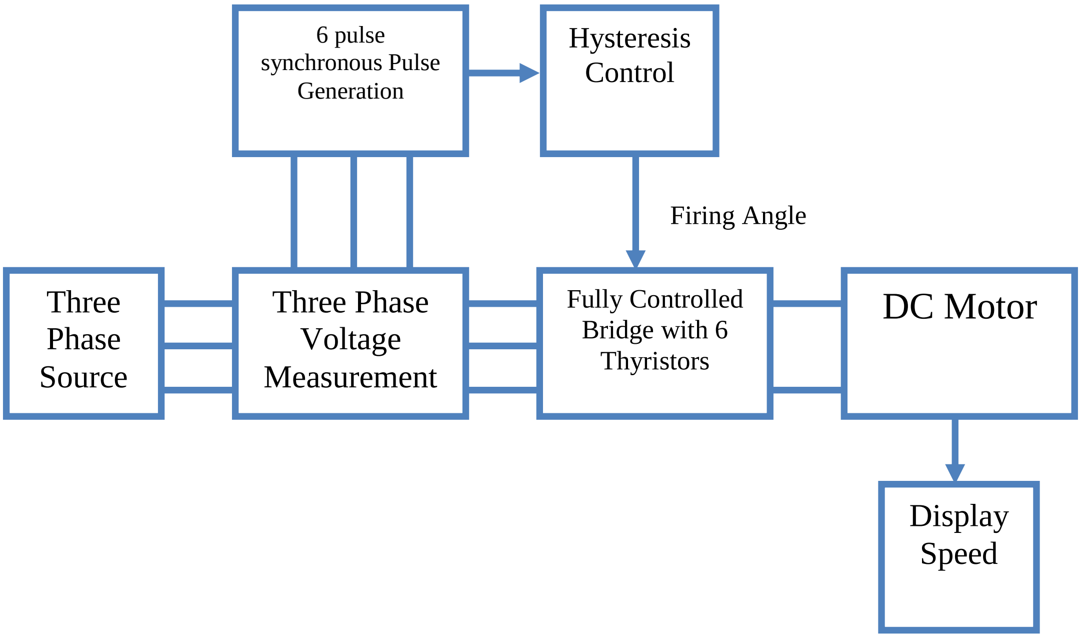

Fig.5 Block Diagram Representation of Proposed Work.

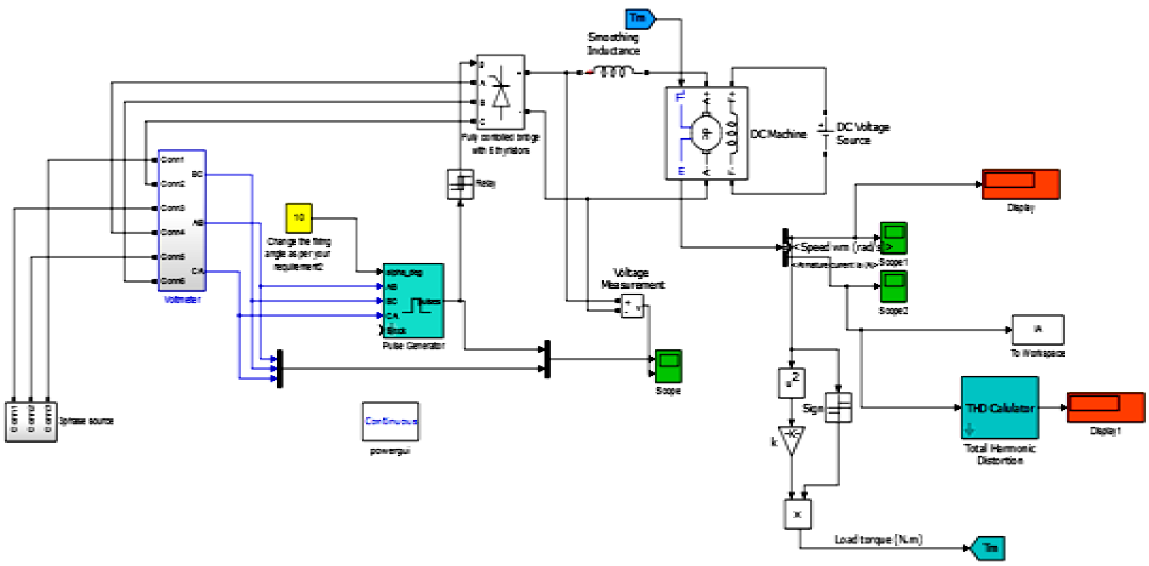

Fig.5 (a) Actual Simulink model of Developed Method.

V. RESULTS AND DISCUSSIONS

The proposed algorithm has been successfully implemented in MATLAB Simulink and results obtained for different values of alpha degrees of synchronous 6 pulse generator are discussed in this section. The results obtained after simulation for different alpha degrees of synchronous 6 pulse generator are tabulated in table (1) and plot of figure

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(6) shows the Variations in Total harmonic distortion of armature current Ia with respect to change in alpha degree of synchronous 6-pulse generator.

Table (1)

S. No.	Alpha degrees of synchronous 6-pulse generator	Total harmonics Distortion in Armature Current Ia (THD)
1	0	3.8
2	5	0.9985
3	10	0.9972
4	15	0.9614
5	20	1.019
6	25	0.3
7	30	0.26
8	35	11.87
9	40	4.677
10	45	0.997
11	50	0.998
12	55	0.9992
13	60	0.9987
14	65	0.9993
15	70	0.9991

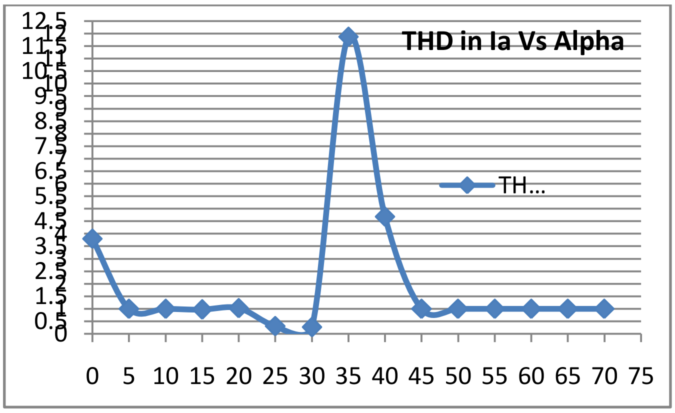

Fig.6 Variation in THD Vs Alpha

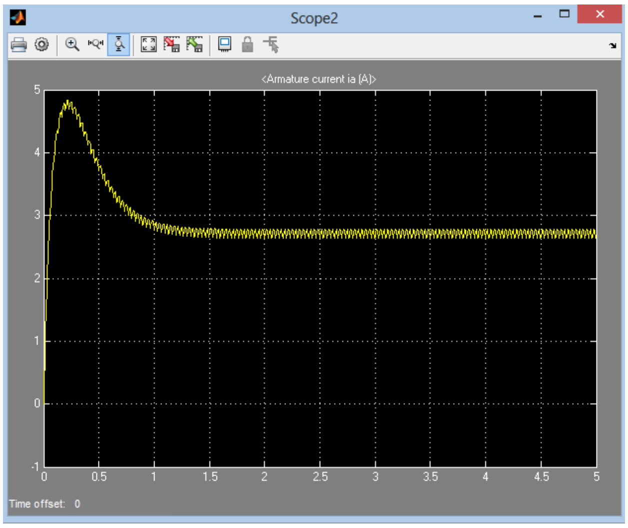

Fig.7 Resultant armature current obtained after simulation for Alpha = 30 degree.

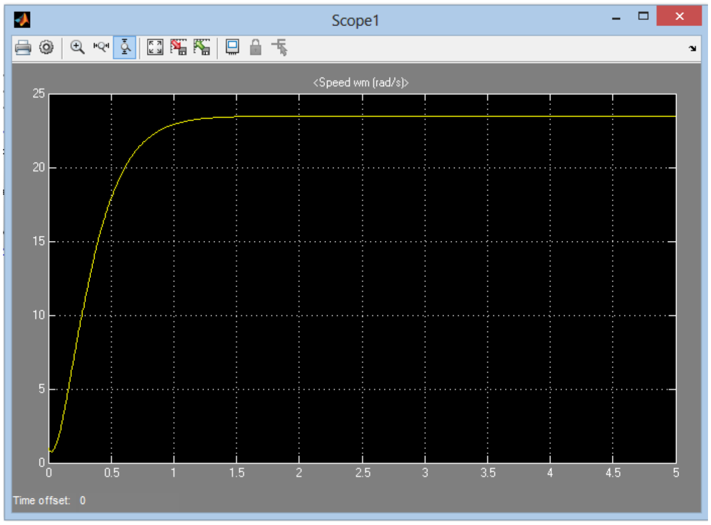

Fig.8 Resultant Speed obtained after simulation for for Alpha = 30 degree.

From figure (6) it is obtained that, developed algorithm provides minimum value of THD in armature current for Alpha = 30 degree. Hence if the value of Alpha is tuned at 30 developed algorithm will provide efficient speed regulation. Figure (7) and figure (8), shows the resultant armature current Ia and regulated speed for Alpha = 30 degree.

Figure (7) shows plot of armature current, from this plot it is evident that the armature current first jumps to its highest value with taking some rise time and then starts decreasing exponentially towards its final value 3 amp. The settling time required for the armature current is approximately 1 sec. since the curve obtained is smooth the harmonics obtained are less, which was not in the case of earlier methods.

Similarly Figure (8), shows the plot of Motor speed obtained from proposed work, which shows that motor speed increases rapidly from zero to 24 rad/sec with exponentially with the settling time 1.5 sec.

VI. CONCLUSION

Speed control of DC motor is successfully implemented in this paper. During performance evaluation of developed algorithm it is found that time requirement is less as compare to available methods.

After the implementation and simulation of developed algorithm it has been found the developed algorithm provides good harmonics reduction in armature current, thus provides efficient speed control over motor speed.

In addition to this the settling time required for motor speed is very small hence the developed algorithm can be used for real time application of DC motor speed control.

However the performance of the developed algorithm depends on the Alpha of synchronous 6-pulse generator. It was found in table (1), that developed algorithm provides minimum value of THD in armature current for Alpha = 30 degree. Hence if the value of Alpha is tuned at 30 developed algorithm will provide efficient speed regulation.

Hence the developed algorithm provides very small THD in armature current at Alpha = 30 degree, and therefore provides efficient harmonics reduction in armature current and hence provides efficient speed control.

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