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Performance Enhancement of Chopper Driven SEDC Motor Using Anti-windup Techniques

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***Abstract*— Osteosynthesis is a type of surgical procedure that stabilizes and joins the ends of fractured (broken) bones by mechanical devices such as metal plates, pins, rods, wires or screws for which it uses low power electric motor like SEDC(Separately Excited DC Motor) to drill and fix the screws. This paper describes about the performance improvement of this motor using anti-windup techniques. The various Performance parameters like fall time, peak overshoot and steady state error are determined for both the conventional PI and anti-windup controlled motor using Simulink model and the comparison of both the controllers is given based on these parameters. The drawback of the conventional PI controlled motor is the large peak overshoot and large steady state error values. This is reduced in the proposed anti-windup controllers and thereby the performance of the motor is improved. The SIMUINK MODEL of both conventional PI and anti-windup controlled motor operation is obtained using MATLAB version R2010a.**

Keywords—Osteosynthesis,SEDC Motor,Anti-windup,peak overshoot, fall time, steady state error,PI(Proportional Integral).

I. INTRODUCTION

Bone is a calcified connective tissue forming the major portion of the skeleton of most vertebrates. A bone is said to be fractured if there is a break in its continuity. Fractured bones are capable to heal itself by producing new bone forming cells and blood vessel at the fracture site. Direct approach bone fracture treatment implicates the internal fixation of fractures using immobilization screws, wires and plates. Bone fracture treatment usually involves restoring of the fractured parts to their initial position and immobilizing them until the healing takes place. Drilling of bone is common to produce hole for screw insertion to fix the fractured parts for immobilization [1]. For the drilling purpose, low power motors like SEDC (Separately Excited DC Motor) and PMDC (Permanent magnet DC motor) are used. For proper drilling the speed and torque of this motor are to be controlled.

II. CHARACTERISTICS OF SEDC MOTOR

There are two general characteristics of this motor[2]. They are

- Speed and Armature Current Characteristics
- Torque and Armature Current Characteristics

A. Speed and Armature Current Characteristics

The Speed of SEDC motor is directionally proportional to back emf/ flux i.e E_b/φ. When load is increased, back emf E_b and φ flux decrease due to resistance drop and armature reaction respectively. However back emf decreases more than φ so that the speed of the motor slightly decreases with load.

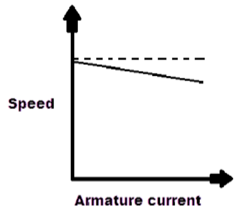

Fig 1. Speed-Armature Current Charateristics

B. Torque and Armature Current Characteristics

In SEDC Motor, torque is proportional to the flux and armature current. Neglecting armature reaction, flux φ is constant and torque is proportional to the armature current Ia . τ – Ia characteristics is a straight lien passing through the origin. From the curve it can be seen that huge current is needed to start heavy loads [3].

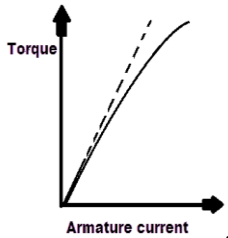

Fig 2. Torque-Armature Current Characteristics

III. PI CONTROLLER

The PI controller is the combination of a proportional and an integral controller. I controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller will not increase the speed of response [4]. The following diagram shows the block diagram of PI controller with a separate proportional and integrator block. This figure is an integral error compensation scheme, where the output response depends in some manner upon the integral of the actuating signal. This type of compensation is introduced by a using a controller which produces an output signal consisting of two terms, one proportional to the actuating signal and the other proportional to its integral. Such a controller is called proportional plus integral controller or PI controller.

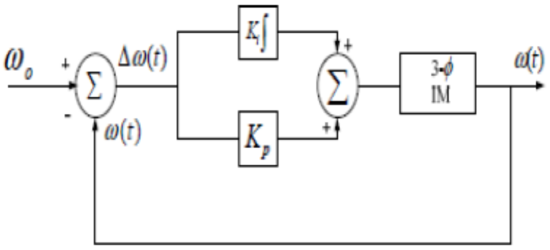

Fig 3. Block Diagram of PI Controller

The output equation of the controller is

$$u(t) = (k_p * e(t)) + (k_i * \int e(t) * dt) \quad (1)$$

The following figure shows the block diagram of PI controller based SEDC motor.

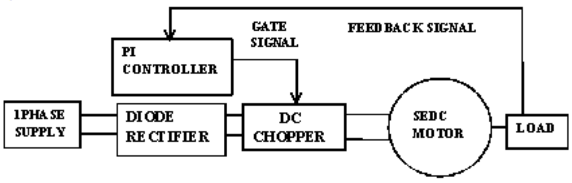

Fig 4. Block diagram of PI Controller based SEDC Motor

IV. ANTI-WINDUP PI CONTROLLER

Under some operating conditions non-linearity in the plant or controller can stop an Integral controller from removing the steady state error. If the Integrator output is not limited, then during this time the total of the integrated (summed) error will continue to build. This becomes a problem when using a PI or PID controller since the integral part of the controller will have the past error in mind, even if the reference signal is finally reached. This problem will lead to an overshoot that will take quite some time for the system to handle, and might involve several oscillations. Once the restrictions are finally removed, problems can arise because this built up “energy” must be removed before the integral control can act normally and this can take a long time. To avoid this, anti-windup circuits are added that place ± limits on the integral total. These limits are usually placed on the summed output of the P&I controller as well This problem during some uncertain conditions is called the **INTEGRATOR WINDUP PROBLEM**.

The following figure illustrates the above mentioned integrator windup problem.

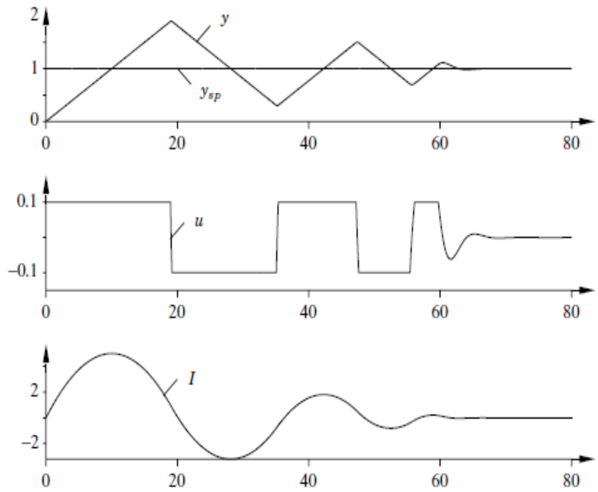

Fig 5. Illustration of Integral Windup

A. *Various Anti-windup techniques*

To overcome the windup problem some anti-windup techniques are used in the proposed methods. The various anti-windup techniques discussed in the proposed method are as follows [5]

- Back Calculation
- Conditional Integration
- Tracking
- Dead Zone

- Tracking with gain

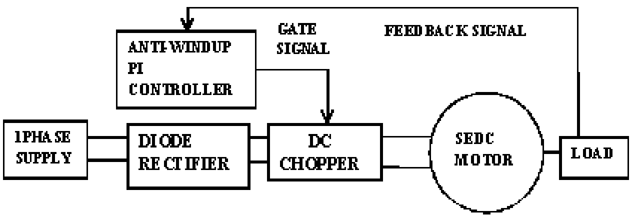

Fig 6. Block diagram of Anti-windup PI Controller based SEDC Motor

The above figure represents the block diagram of Anti-Windup controller based SEDC Motor control where the PI controller shown in the figure 4 has been replaced by the Anti-Windup controller where the integral windup problem can be rectified and thereby the performance of the motor can be improved.

V. Results and Comparison

The simulink model of both PI controller based SEDC motor control and the anti-windup PI controller based SEDC motor control was done in MATLAB R2010a. The fllowing fogures shows the simulink output of both the PI Controller and Anti-windup PI controller.

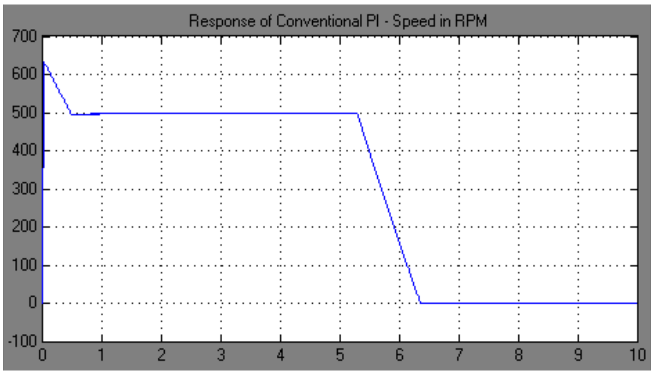

Fig 7. PI Controller output for set speed of 500 RPM

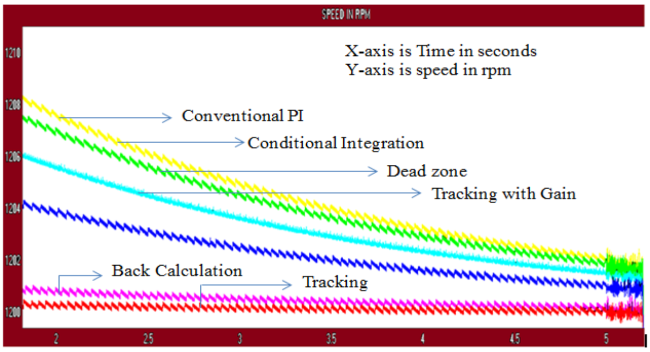

Fig 8. Steady state error comparison for PI and Anti-windup controllers for 1200 RPM set speed

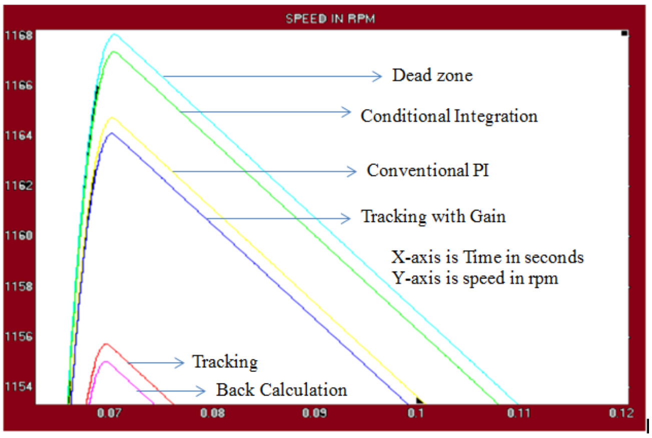

Fig 9. Peak Overshoot comparison for PI and Anti-windup controllers for 1100 RPM set speed

From the figure 8 and 9 it is clear that the back calculation and Tracking controllers has less peak overshoot and steady state error compared to other controllers.

VI. REFERENCES

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