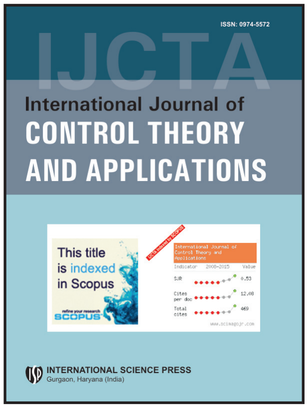

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Buck Converter Fed DC Motor for Optimized PI-Controller Design

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Abstract: A dc motor find wide application in industries and the speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field winding. The dc motors are used in propulsion electric vehicles, elevators, robot and hoists. To achieve the desired level of performance the motor requires suitable speed .the speed control is achieved by conventional PI- controller. Although conventional controllers are widely used in the industry due to their simple control structure and ease of implementation, these controllers pose difficulties. This project presents the optimized technique of particle swarm optimization and used to tune PI gain of the controller. For the purpose of comparison with conventional PI controller are considered from the simulation result, PSO technique offers an improvement in the quality of the speed response and better performance.

Keywords: Particle swarm optimization technique (PSO), Proportional-integral (PI) controller.

1. INTRODUCTION

DC motors are widely used in systems with high control requirements. Thus, rolling mills, double-hulled tankers, and high precision digital tools can be mentioned as examples of such systems. Generally, to control the step less velocity and smoothness, adjustment of the armature voltage of the motor is used while, certainly, applying PWM signals with respect to the motor input voltage is one of the methods most employed to drive a DC motor. However, the underlying hard switching strategy causes an unsatisfactory dynamic behavior, producing abrupt variations in the voltage and current of the motor These problems can be addressed by using DC/DC power converters, which allow the smooth start of a DC motor by applying the required voltage in accordance with the one demanded for the performed task, being usually the tracking of either a desired angular velocity trajectory or a desired angular position trajectory. In particular, the DC/DC Buck power converter has two energy storing elements (an inductor and a capacitor) that generate smooth DC output voltages and currents with a small current ripple, reducing the noisy shape caused by the hard switching of the PWM. Thus, in order to achieve the angular velocity trajectory tracking task of the DC/DC Buck power converter–DC motor system, this paper focuses on the design of a PI-controller with optimization technique. some literature survey's are Lyshevski et. al., (2000) introduced a fourth-order mathematical models for some combinations of DC/DC power converters coupled to a DC motor and, additionally, designed classical proportional-integral (PI) controllers for the regulation of the motor angular velocity. The advantages of this paper is Generating the trajectory involves stretching the path in time, the maximum velocity is obtained. The disadvantage of this paper Planning algorithm is used to control the trajectory tracking of the system .Linares-Flores et. al., (2006) presented a design for smooth angular velocity controllers for a DC/DC Buck converter–DC motor system, wherein the effectiveness of the proposed controllers was verified only by numerical simulations. In a smooth starter, based on the differential flatness approach, to regulate the velocity of a DC motor powered by a DC/DC Buck converter was presented. This starter was designed through a simplified second-order model, obtained by considering the motor armature inductance and the converter capacitor current to be negligible. Similarly, in they introduced an average GPI control law, implemented through a $\Sigma-\Delta$ modulator, for the angular velocity trajectory tracking task, exploiting the flatness of the combined system. To accomplish this, they employed the mathematical model obtained *i* Likewise, for the same system and task, the design of a dynamic output feedback controller was presented, based on a fourth-order model deduced in, carried out by using the energy shaping and damping injection method. The disadvantages are Lack of flatness and Enhance the features then the Steady state error and the external torque is interrupt the output. Antritter et. al., (2007) presented a controller for the angular velocity trajectory tracking task, based on the differential flatness and a fourth order model, for a DC/DC Buck converter–DC motor system. The controller was experimentally implemented by using a PWM through data acquisition cards. However, in both works no experimental validation was included when parametric uncertainties appeared in the system. Sureshkumar et. al., (2010) compared for the same system, via numerical simulations, the performance of both PI and back stepping controllers associated with the regulation of the angular velocity of the aforementioned system. Bing¨ol et. al., (2012) presented a virtual laboratory, for the angular velocity task, that included a neural network controllers training set for a DC motor powered by a DC/DC Buck converter. This set allows the DC motor and controller parameters to be changed, and the system's reaction under various operational conditions to be monitored by means of a graphical user interface. H–infinity controller, with pole clustering based on linear matrix inequalities techniques to control the velocity of a DC motor driven by a DC/DC Buck converter, was presented. The results showed, via numerical simulations, that the proposed control scheme guarantees fast angular velocity tracking with minimal duty cycles. Sira-Ram´ırez et. al., (2013) described a robust control law based on active disturbance rejection control and flatness-based control, taking into account an unknown time-varying load, for two combinations of DC/DC Buck converters and DC motors. Numerical simulations showed the robustness of this technique for the angular velocity control of the motor shaft. Silva-Ortigoza et. al., (2013) introduced a two-stage control based on differential flatness for the angular velocity control without taking into account velocity measurements of a DC/DC Buck converter–DC motor system. They showed, through numerical simulations that included a $\Sigma-\Delta$ modulator that the proposed control scheme effectively provides robustness to the tracking performance when parametric uncertainties related to the system appear. Silva-Ortigoza et. al., (2015) The hierarchical control approach employed in mobile robotics, where the mathematical equation that governs the high hierarchy control imposes to a low hierarchy control, by means of an inner control loop, the desired trajectory to be followed. The main contribution of this paper is to propose a hierarchical controller that carries out the angular velocity trajectory tracking task for the DC/DC Buck converter–DC motor system. To achieve this, as a variation of (i), two independent controllers are designed; one for the DC motor (via differential flatness) and another via the cascade scheme (through the SMC and PI control) for the Buck converter, which are then interconnected in order to work as a whole. Additionally, experimental validation of the proposed hierarchical controller's performance is included, showing how the trajectory tracking task is successfully accomplished, even when abrupt variations of the system parameters appear, so exhibiting the robustness of the controller presented and it obtained. The problem stated in the exciting system is investigation and state space analysis and transformation and simulate the state space analysis of comparative evaluation controller. In my project, the particle swarm optimization is used to control the speed and stimulate in matlab software to get a desired speed.

2. DC-DC BUCK CONVERTER-DC MOTOR SYSTEM

The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized converter, all the components are considered to be perfect. Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance as being infinite).

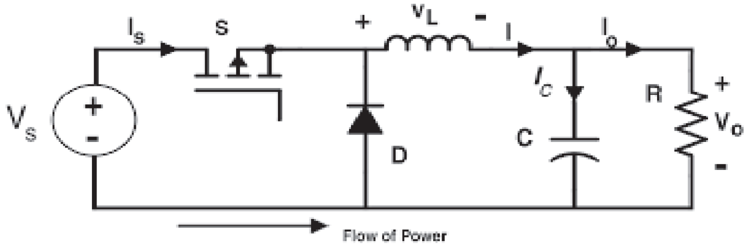

Figure 1: Schematic diagram of buck converter

The conceptual model of the buck converter is best understood in terms of the relation between current and voltage of the inductor. Beginning with the switch open (off state), the current in the circuit is zero. When the switch is first closed (on state), the current will begin to increase, and the inductor will produce an opposing voltage across its terminals in response to the changing current. This voltage drop counteracts the voltage of the source and therefore reduces the net voltage across the load. Over time, the rate of change of current decreases, and the voltage across the inductor also then decreases, increasing the voltage at the load. During this time, the inductor stores energy in the form of a magnetic field. If the switch is opened while the current is still changing, then there will always be a voltage drop across the inductor, so the net voltage at the load will always be less than the input voltage source. When the switch is opened again (off state), the voltage source will be removed from the circuit, and the current will decrease. The changing current will produce a change in voltage across the inductor, and now the inductor becomes a voltage source. The stored energy in the inductor's magnetic field supports current flow through the load. During this time, the inductor is discharging its stored energy into the rest of the circuit. If the switch is closed again before the inductor fully discharges (on state), the voltage at the load will always be greater than zero. for the DC/DC Buck power converter–DC motor system, which is shown in Figure 2. Such a control has the following components:

1. In the high hierarchy level, a control based on differential flatness, #, which executes the angular velocity trajectory tracking task, has been developed for the DC motor. This control corresponds to the desired voltage profile that the output voltage of the Buck converter has to track.
2. In order to assure that the converter output voltage, tracks #, a cascade control is developed in the low hierarchy level. In this control, the inner current loop uses SMC, while the outer voltage loop uses a PI control.
3. Finally, by means of the hierarchical control approach, the controllers developed in (1) and (2) are interconnected to carry out the angular velocity trajectory tracking task of the system.

The below Figure 2 will discuss about the dc motor is directly fed to the buck converter. To control the desired speed with pulse generator. Then it is termed as open loop system. In the low hierarchy level also it control the angular velocity. The dc-dc buck converter- dc motor system are shown below:

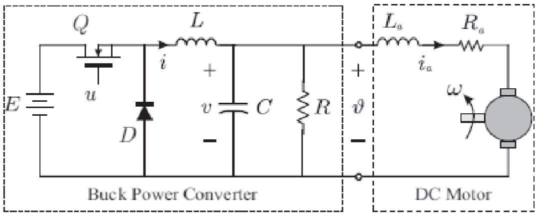

Figure 2: DC-DC buck converter- DC motor system

Control of a DC Motor

In this subsection, the design of a controller by applying the differential flatness concept for a DC motor is introduced. For the design, the motor inductance is considered different to zero and a DC motor mathematical model expressed in terms of the angular velocity is employed, given by

$$\mathrm{L}_a \frac{di_a}{dt} = \vartheta - \mathrm{R}_a i_a - k_e \omega$$

$$\mathrm{J} \frac{d\omega}{dt} = -b\omega + k_m i_a$$

where, v is the applied voltage in the motor armature terminals, i_a is the armature current, k_e is the counter electromotive force constant, k_m is the motor torque constant, L_a is the armature inductance, R_a is the armature resistance, J is the moment of inertia of the rotor and motor load, and b is the viscous friction coefficient of the motor.

Further, without loss of generality only the angular velocity variable is taken as flat output, being

$$\mathrm{F} = \omega$$

Control of a DC/DC Buck Power Converter

From the results obtained in the previous subsection it is observed that the voltage profile # is required by the DC motor to track the desired angular velocity trajectory w^*. It must be remembered that v is produced by a Buck power converter.

Therefore, it naturally arises the need to develop a control scheme for the converter that allows to reproduce the desired voltage profile v. Thus, the purpose of this subsection is to present a cascade control for the Buck converter similar to those presented for Boost, Buck-Boost, Non-Inverting Buck- Boost, and Cuk converters respectively. It is important to mention that those controllers were only designed for the regulation task. In contrast to those controllers, this subsection gives the solution for the voltage trajectory tracking task of the Buck converter output. The electronic circuit of the Buck power converter is shown in Figure 1. The input of the buck converter is done in mathematical is given below

$$u = \frac{1}{2}[1 - \mathrm{sign}(s)]$$

The desired voltage for the buck converter v^* is determined by the voltage profile v obtained from controlling the dc motor which allows the angular velocity trajectory tracking task for dc-dc power system to be carried out.

$$v^* = \vartheta$$

3. CONTROLLER DESIGN

The buck converter is given the low voltage and run DC motor. The error of the motor will be controlled by PI-controller with pso technique. The main goal of our project is to achieve the desired speed and control the process, the Figure 3 shows the closed loop diagram with optimization technique.

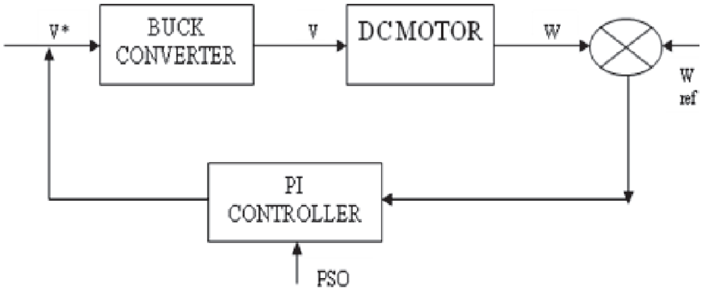

Figure 3: Block diagram of closed loop system

The dc-dc power converter constructs in and operation of DC motor, PI-controller design and PSO – optimization technique are described. Practically we achieved the desired speed using particle swarm optimization technique. the buck converter is used to step down the voltage (v) and input of the DC motor is voltage profile (v^*). The DC motor is run at low voltage. It cannot reach the desired speed. It control by PI-controller. Then we get desired value of k_p and k_i value. It is a closed loop. The supply is 56V and it get desired constant speed 120rpm.the application of my project is robot.

4. SIMULATION RESULT

In the closed loop system, the speed is controlled by PI-controller. The supply voltage is 56V. The power converter steps down the voltage and control the speed. The Figure 4 shows the simulation diagram of closed loop with optimization technique.

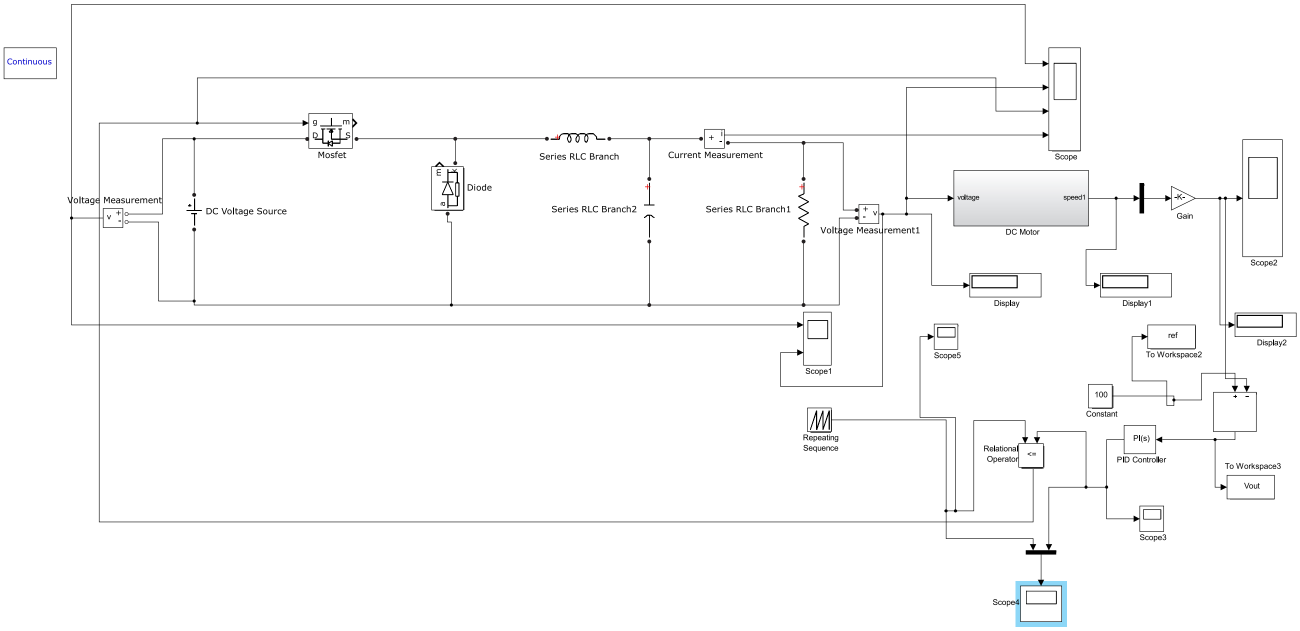

Figure 4: Closed loop system

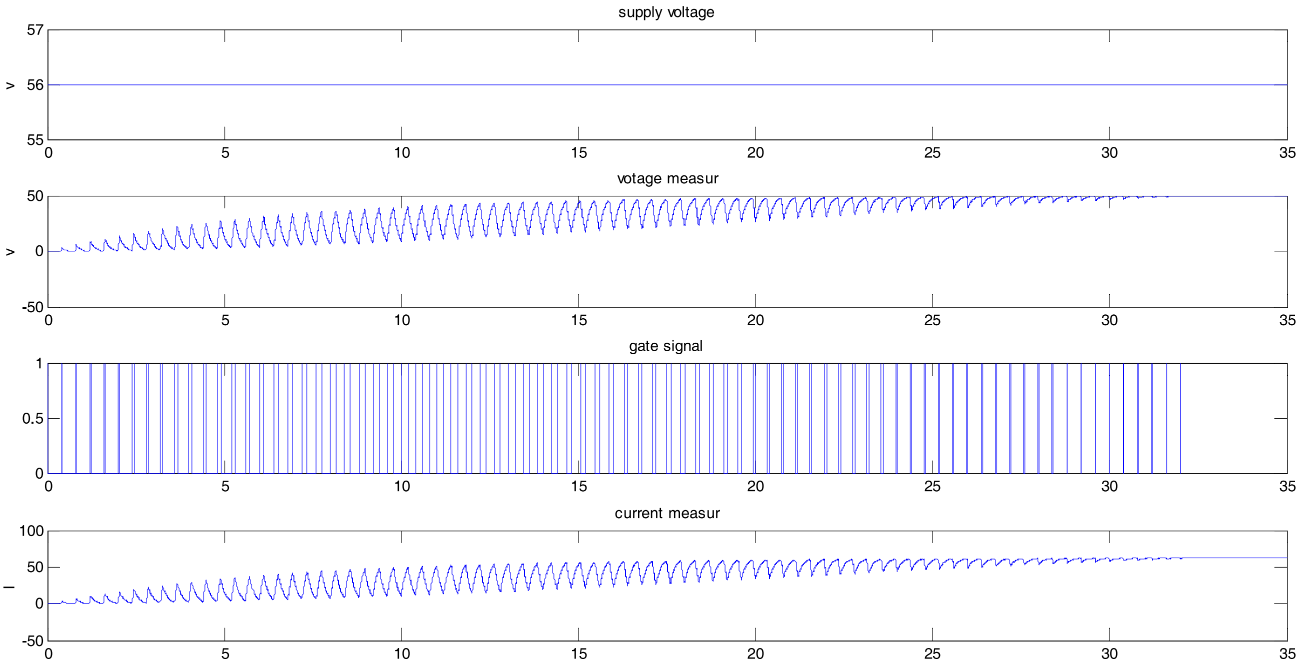

Figure 5: Voltage and current waveform

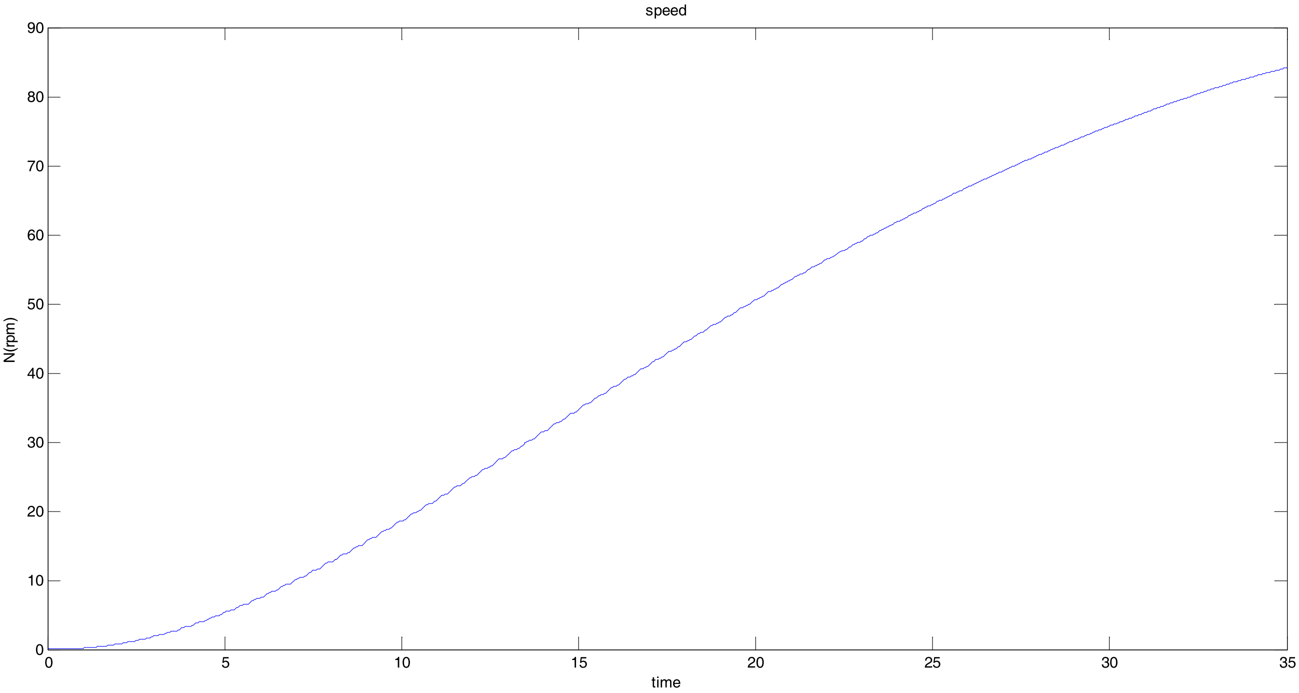

Figure 6: Speed wave form of closed loop system

The step down voltage is reached 47V. The settling time is above 30. The speed wave form of Figure 6 with PSO technique each step time it give good performance to the speed and settling time of voltage and speed. It constantly reaches the speed 120rpm. The settling time of PI-controller with pso technique is above 35.each step time it will give better simulation. The simulation result of closed loop is obtained by matlab/simulink. The optimization technique is given better desired speed for each step time.

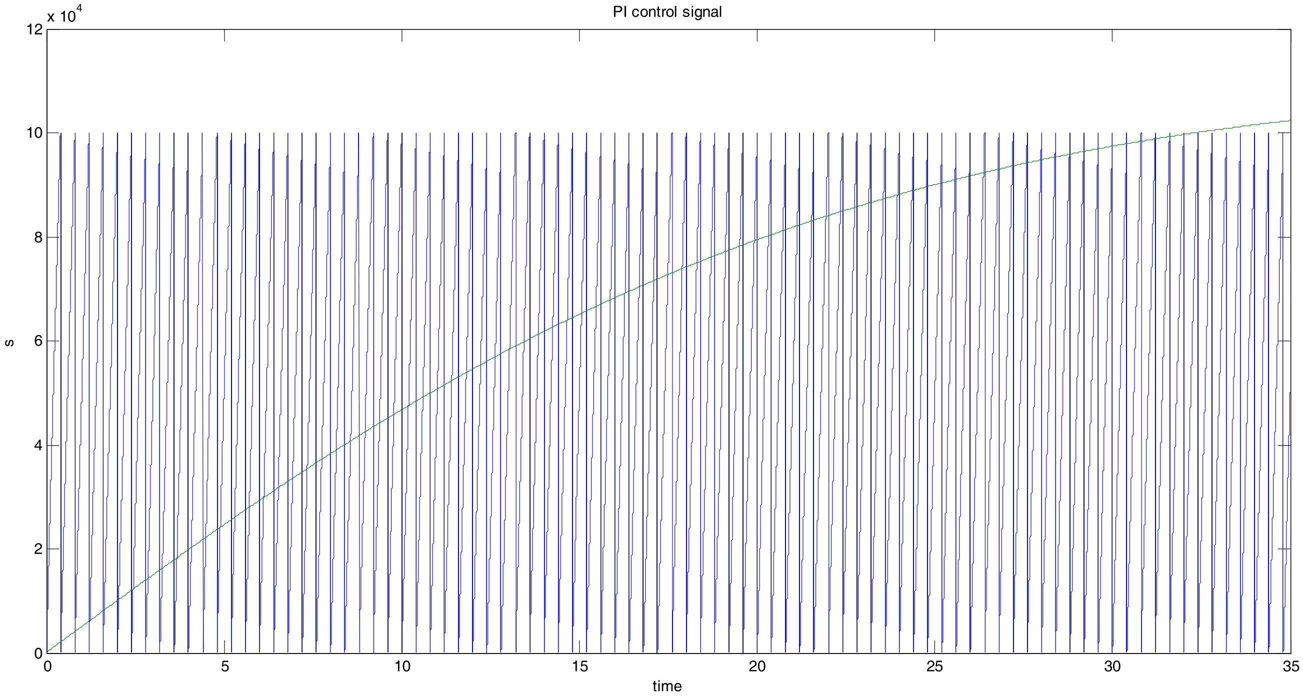

Figure 8: PI-controller wave form of closed loop system

5. CONCLUSION

The speed control is achieved through by processing optimization technique in PI-controller (Particle swarm optimization). The best result is obtained when compared to PI-controller (trial and error method). This optimization technique improves the speed at each step time. Therefore the simulation is done in Matlab software. A future enhancement of my project it decided to implement cuckoo search optimization technique to achieve the desired speed.

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