# An Advanced Double Generalized Predictive Controller For The Speed Control of PMBLDC Motor

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**Abstract –** A cascade GPC for speed control of PMBLDC motor is proposed in this paper. The inner loop uses Generalized Predictive Controller (GPC) to develop in sequence conveyed by accessible disturbances, although outer loop used a Generalized Predictive Controller (GPC) to control the error from nonlinear identification of the generalized system based on PMBLDC motor models. Simulation results show that cascade Generalized Predictive Controller (GPC) outperformed than the fine tuned cascade PI controller. In addition to the results established the suitable system output and flat feasible control procedures of the double Generalized Predictive Controller (GPC). The proposed double GPC system successfully replaces the fine tuned cascade PI control algorithm. A new GPC algorithm is developed for PMBLDC motor for energy efficient operation. New algorithm optimizes the system with cost function. Prediction algorithms do best for internal components of the drive.

**Keywords:** Cascade GPC, Speed control, PMBLDC motor, nonlinear identification, generalized system, Prediction algorithms

## 1. Introduction

The speed and position of PMBLDC motor is generally controlled in a multi loop structure by means of inner current loop and outer speed loop. The loop interruption occurs in the current loop and speed loop, while the motor is controlled by a particular system. Likewise, while the motor is operating in a distributed control conditions, the delay arises in the communication network. When the loop delay is not foremost, proportional plus integral control is very efficient. However, the difficulties caused by the delay time cannot be expected by the PI controller. So, the time management connecting inner current loop and the outer speed loop acting an important role in the industrial motor control systems, because of loop delay the noise is created in the switches and fluctuations in the motor power supply and thus the motor settles at the chosen set point with extra oscillations. If the control loop delay is properly rewarded, lot of power can be saved because of decrease in losses in the internal components of the drive. Therefore, it is preferred to develop a controller that has the capability to supervise the time delay and adapt online, according to the situation in which it works to yield satisfactory control performance. To defeat these drawbacks, an advanced control schemes such as Smith predictor performs well only if the motor model is precise but the performance degrades with imprecision in motor system gain and interruption time. Self-tuning regulation can be used to control motors with unknown dynamics. Nevertheless, adaptive or self-tuning algorithms require robustness while applied to system with improperly modeled motor delay. So, an alternative design approach is required for conventional cascade speed control scheme.

## 2. Conventional Controller

The prominent controller in the motor control drive is the cascade PI/PID controller. The controller design and tuning of PI controller coefficients, to present finest performance is forever a contentious issue. Another issue is that because of its structure, a PID controller acts only after a disturbance has moved the process output from its preferred path. Thus PI controller is virtually difficult and requires group of manipulations and retuning methods. The cascade control scheme is the universal standard for the control of electric drive systems as shown in Fig.1

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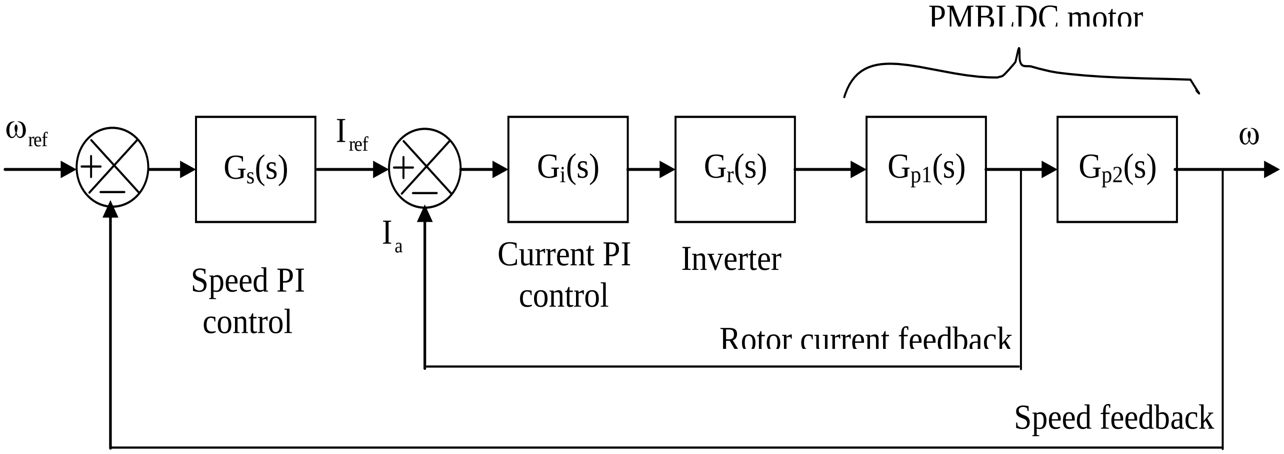

**Fig. 1.** Block diagram of cascade PI speed control for PMBLDC motor system

The speed controller Gs(s) computes an output signal that is the torque needed to accelerate the motor to the desired speed. The desired current Ia(s) that the motor needs to produce the torque is calculated from the mathematical model of the motor. The inner loop controls the current that is needed to produce the torque. The output of the controller Gi(s) is used as set point to the power converter which produces the essential input voltage to the motor. The transfer function as of the rotor current set point Ia(s) to the rotor current is the closed loop transfer function of the inner loop and is given by

$$G_s(s) = \frac{I_a(s)}{I_a{}'(s)} = \frac{G_i(s)G_r(s)G_{p1}(s)}{1+G_i(s)G_r(s)G_{p1}(s)} \qquad (1)$$

Where

$G_s(s)$ is the speed control loop

$G_i(s)$ is the current control loop

$G_r(s)$ is transfer function model of the power converter

$G_{pl}(s)$ is the electrical part of the PMBLDC motor.

$G_{p2}(s)$ is the mechanical part of the PMBLDC motor

If the gain of the speed controller is huge, next the inner closed loop controller determination approach to unity and will also be reasonably not sensitive to variations in the power converter and/or motor transfer functions. Non-linear behavior of the motor and converter be able to often be modeled through transfer functions by means of variable coefficients. From the output of the speed controller there are three quite simple systems in series, the speed controller, the current control loop $G_i(s)$ and the mechanical part of the motor model $G_{p2}(s)$. Thus the cascade structure eliminates a lot of the intrinsic difficulty in the power converter and motor dynamics. However, windup problem in cascade control systems desires particular attention as shown in Fig.2. Also, both speed and torque tracking objectives are achieved in coordinated and incompatible parameter case. The measured and unmeasured strife are to be efficiently discarded and the motor should run at preferred speed at constant load. In addition, non-minimum phase characteristics of the motor and motor constrain lead to a problem. To overcome these drawbacks, this work applies a double generalized predictive controller (GPC) to the PMBLDC Motor system in an existing cascade control structure. GPC control is an online optimization approach to satisfy multiple, changing performance criteria, under existing PMBLDC Motor control hardware scheme. Therefore, the multirate based general predictive control law is proposed for the conventional cascaded PI-PI scheme, in which both the current and speed control loops are configured with new general predictive control algorithm.

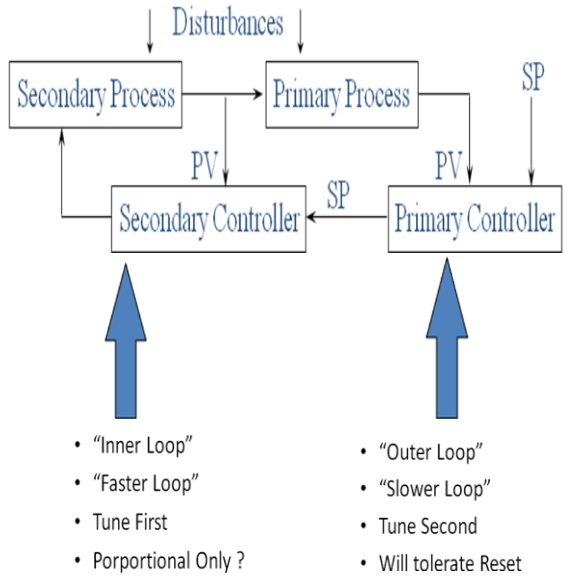

**Fig. 2.** Block diagram of cascade orientation

## 3. Proposed Cascaded Double GPC

### 3.1 Basics of GPC

Generalized predictive control developed by Clarke et al [48, 49, 50, 70] is one of the most popular predictive control strategies. Predictive control, commonly grouped as model predictive control (MPC), uses a model of the plant to predict the output in the future. The interest in developing a multirate cascade control system using GPC is the possibility to control the speed and current together. To realize this, two GPC control algorithm is computed as shown in the Fig.3

Where

yt - is the resulting control signal applied to the motor.

u - is the inner signal coming from the minimization of GPC.

The speed and current loops of the cascaded structure require the double generalized controller (GPC) algorithms and therefore the minimization of cost function. It is also necessary to express the numerical models of GPC to the individual loops.

### 3.2 Numerical Model of GPC

A cascaded predictive approach initial requires the characterization of the numerical model for both speed and current loops of the PMBLDC Motor system. regularly, the time varying system dynamics be able to describe a proscribed autoregressive and integrated moving average (CARIMA) model for a general ' r ' inputs and ' n ' outputs system with u, measurable input disturbances. This can be expressed as

$$A(q^{-1})y(t) = B(q^{-1})u(t-d) + \frac{C(q^{-1})\varepsilon(t)}{\Delta} + D(q^{-1})u_d(t-d) \qquad (2)$$

Where

q-1 is delay operator

y (t) is the predictive controller output vector

u (t-d) is the manipulated variable with delay

ε ( t ) is uncorrelated random noise

Δ is the difference operator 1-q-1". In most of the cases C (q-l) =1

A,B,C and D are matrices of polynomials in the delay operator (q-1) with dimensions n x n, n x r , n x n and n x nd respectively.

The output vector for 'n' output system is expressed as

y (t) = [y1(t)y2(t). ...................yn(t)]T

The manipulated variable vector for 'r' input system is expressed as

u(t) = [u1(t)u2(t) ....................ur(t)]T

The 'n' manipulated variable disturbance vector is expressed as

ud(t) = [ud1(t)ud2(t) ................... und(t)]T

The uncorrelated random noise vector for 'n' output is expressed as

ε( t ) = [ε1( t ) ε2( t )……… εn( t )]T

### 3.3 Controller Formulation for PMBLDC motor

The main objective of the GPC is to detect the changes in manipulated variable with a system delay time of one sampling instant is

$$\Delta u(t) = u(t) - u(t-d) \qquad (3)$$

Which would create the output most excellent match to a aim value in the presence of disturbance and system constrains. In long range predictive control, a predicted projection of outputs over p-future time intervals to is matched to the set point trajectory by prescribing the sequence of m- future moves

**Outer GPC1 model**

$$A_1(q^{-1})y_1(t) = B_1(q^{-1})y_2(t) + \frac{\varepsilon_1(t)}{\Delta} \qquad (4)$$

**Inner GPC2 model**

$$A_2(q^{-1})y_2(t) = B_2(q^{-1})u(t-d) + \frac{\varepsilon_2(t)}{\Delta} \qquad (5)$$

The proposed cascade dual GPC algorithm is implemented as follows

Step 1: Set sampling time for the external and inner loops as T1 and T2.

Step 2: Set maximum, minimum predictive horizon and control horizon for the two loops.

Step 3: estimate the CARIMA model to yield G1, G2 and P1, P2

Step 4: compute matrix G1, G2 and

$$(G_1^T G_1 + \lambda_1 I_{N11})^{-1} \qquad (6)$$

$$(G_2^T G_2 + \lambda_2 I_{N22})^{-1} \qquad (7)$$

Step 5: Determine the variables Uopt1and Uopt2 based on Eqns.

$$U_{opt1} = (G_1^T G_1 + \lambda_1 I_{N11})^{-1} G_1^T (w_1 - P_1) \qquad (8)$$

Step 6: Set the increment as k=k+1, go back to step

$$U_{opt2} = (G_2^T G_2 + \lambda_2 I_{N22})^{-1} G_2^T (w_2 - P_2) \qquad (9)$$

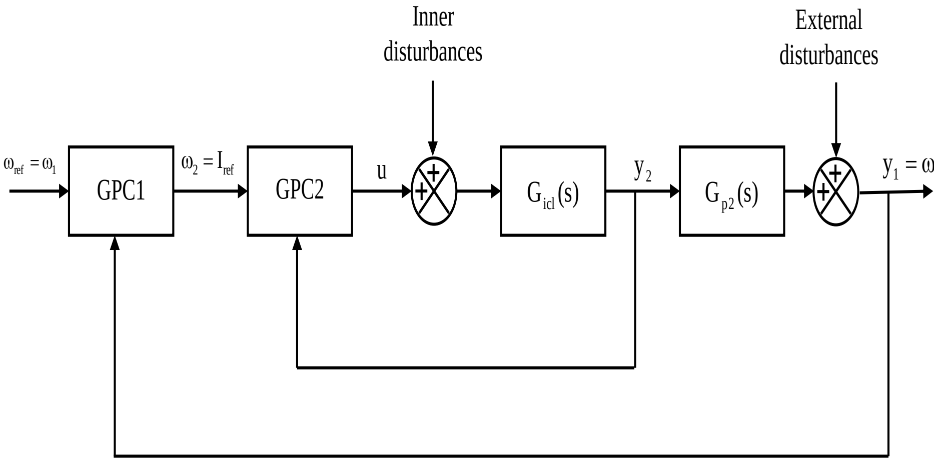

**Fig. 3.** Block diagram of cascade double GPC for PMBLDC motor system

## 4. Simulation Results and Discussion

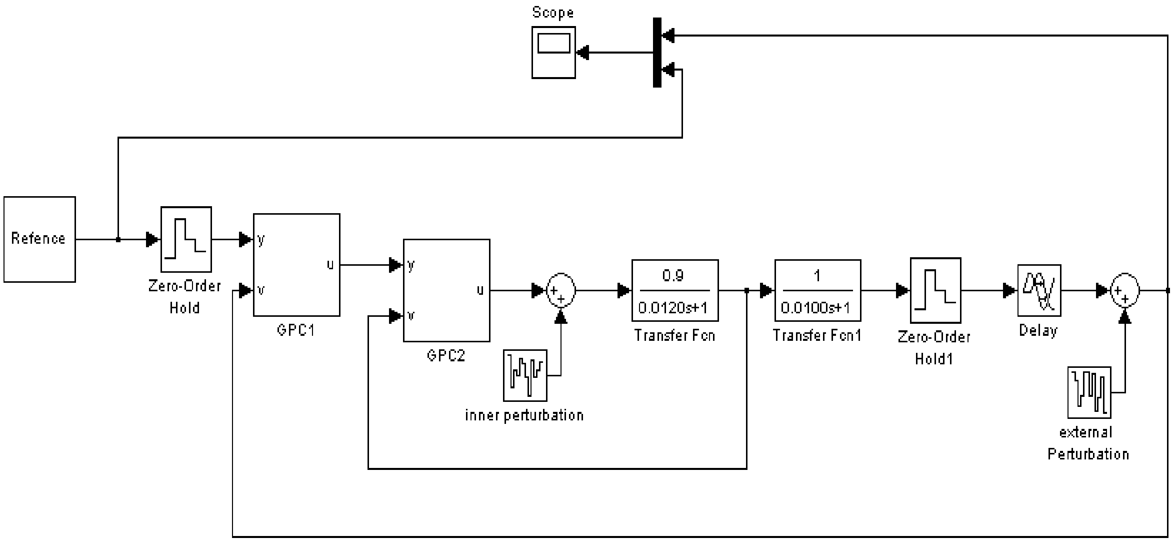

**Fig.4.** Simulation diagram for cascade double GPC

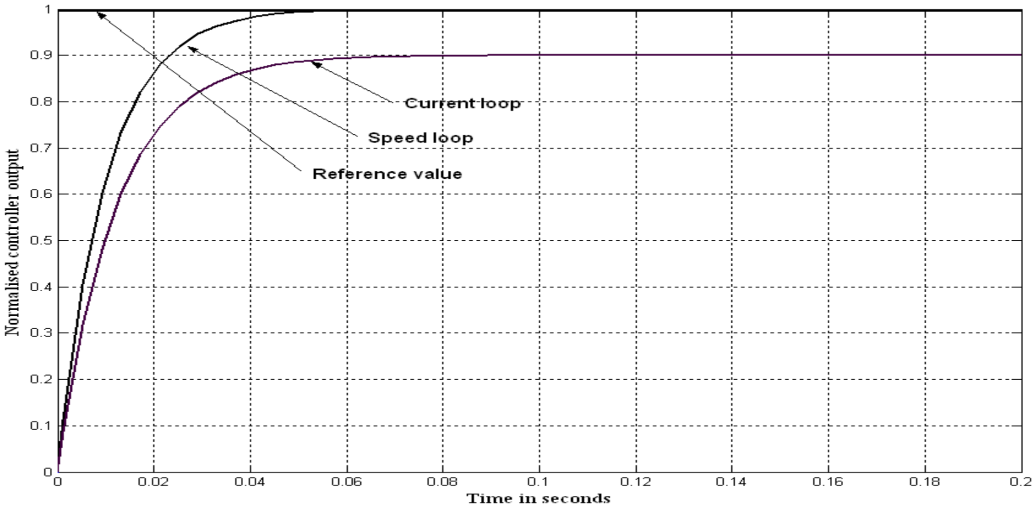

**Fig.5.** Response of the speed control variable for the given step reference

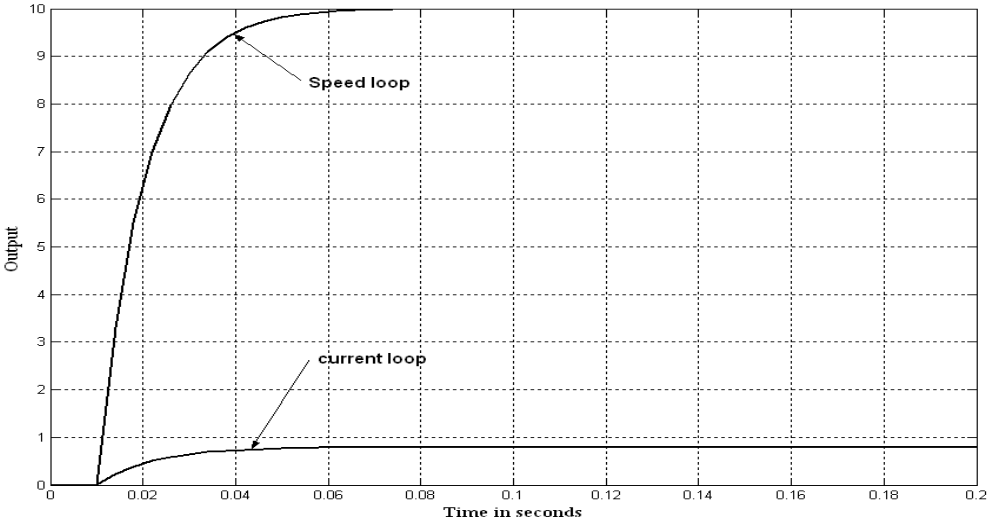

**Fig.6.** Output responses to speed and current loops

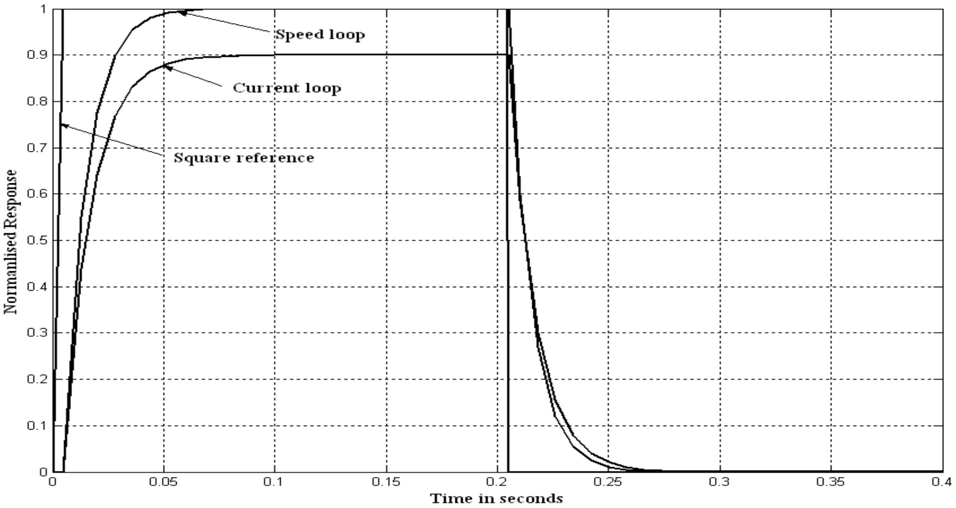

**Fig.7.** Speed loop response for the given square wave reference

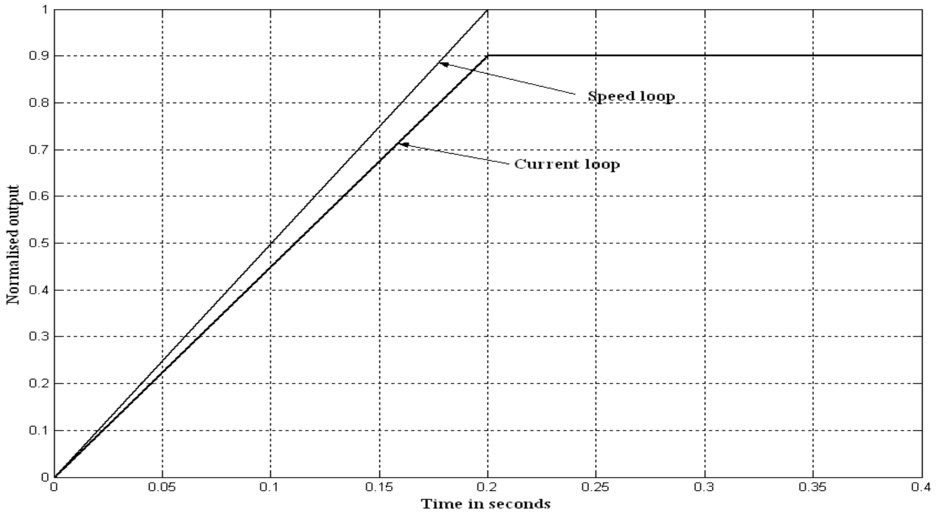

**Fig.8.** Output of the speed loop with increasing ramp reference

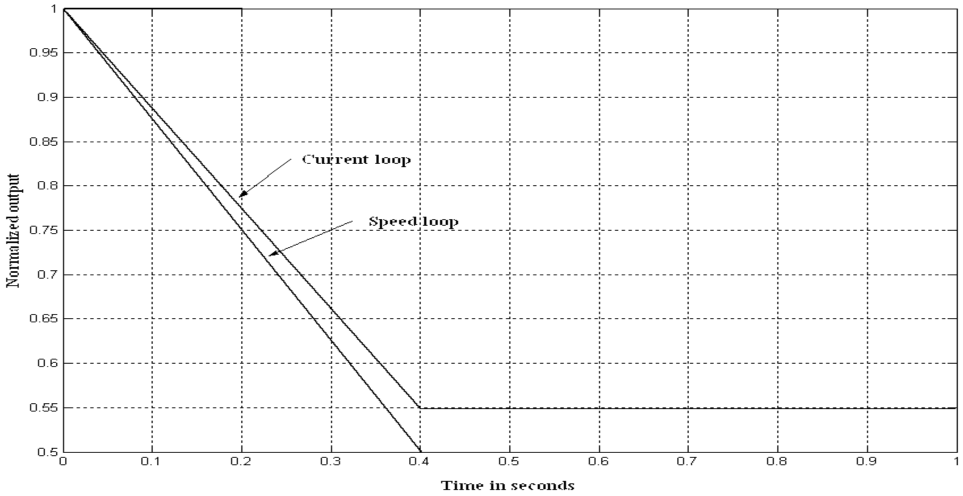

**Fig.9.** The output of current and speed loops with ramp decreasing ramp reference

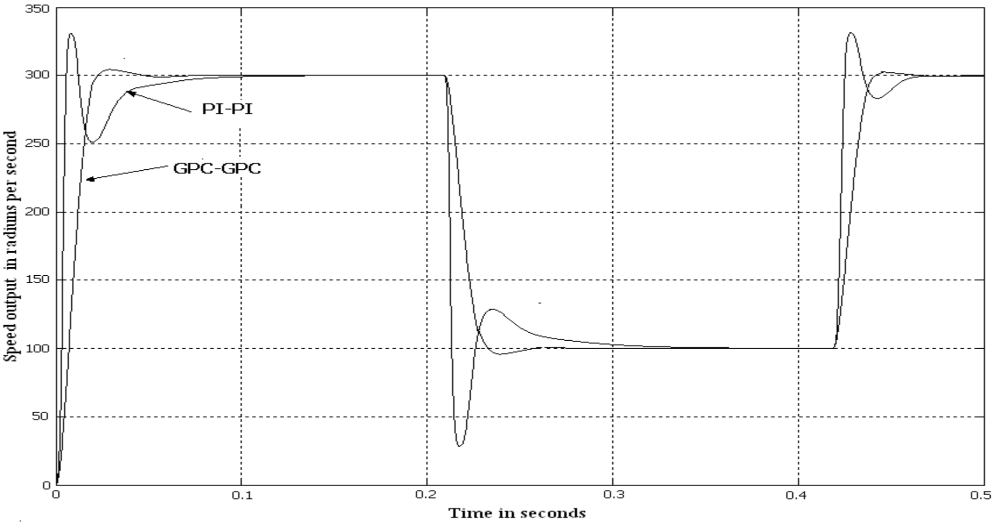

**Fig.10.** Comparison of cascade PI algorithm with DGPC algorithm for variable step

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## 5. Conclusion

The inner loop was used an adaptive based model predictive controller, exploiting in sequence conveyed by reachable disturbances, whereas outer loop used a GPC to control the error from nonlinear identification of the generalized system. Outperformed than the well tuned cascade PI controller. A satisfactory system output and smooth feasible control actions can be achieved.

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