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Starting Analysis of Separately Excited DC Motor by PI Controller

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Abstract: **DC to DC Buck converter- separately excited DC motor system model are smoothly starting by using proportional integral (PI) and resistance starter (traditional mechanism) are presented in this paper. The DC motor widely used in industry because of the simple strategies required to achieve the better performance in speed control applications. By using proportional integral (PI) controller A separately excited DC motor is mostly controlled. The required angular speed trajectory tracing work of a DC motor is tested through with traditional mechanism (resistance starter) and Proportional Integral (PI) control Using MATLAB-Simulink to prove the best. Performances of the controller are examined in terms of the armature voltage, armature current, angular velocity and electromagnetic torque. The obtained results show that the required angular speed trajectory is better traced under abrupt parameters variations in the system.**

Keywords: DC motor, smooth starter, PWM switching, DC-DC Buck converter, trajectory tracking, proportional integral control (PI), resistance starter

I. INTRODUCTION

The system with high control requirement in industrial applications such as rolling mills, battery operated vehicles, cranes, and domestic appliances for these DC motor are mostly used because it is wide, simple and continuous characteristics. Since, it is important to control the speed of a DC motor. By using conventional PI controller, separately excited DC motors are generally controlled because they designed easily, inexpensive maintenance, low cost, and effectiveness. [1] With only the PI controller applied to control of separately excited DC motor, a better performance of characteristics of the controller can be obtained, if all the parameters of DC motor and operating conditions such as load torque, disturbances are exactly known. Under external disturbances and the machine parameter variations the performance of the PI controller for speed regulations reduces. Furthermore, the PI controller achieves have to be carefully selected in order to obtain a desired response. [3, 5] The DC motor is mostly used for controlling the velocity, adjustment of the armature voltage and the smoothness for starting. By applying PWM signal with respect to motor input voltage is one of the starting methods of a DC motor. Starting of a DC motor, generally by rated voltage, at starting, there is no back e.m.f. in the armature, when the motor is stationary. Hence, if the motor is directly switched on the mains, the armature will draw a heavy current (I_a=V/R_a) because of small armature resistance.

DRAWBACKS

1. When starting of DC motors, it is possible to observe unexpected transient problems in the armature circuit, such as variations in the armature voltage, armature current, and angular velocity of the motor shaft.
2. Due to excessive heating effect Burn the armature circuit.
3. Due to heavy sparking Damaging the commutator & brushes.
4. In the line to which the motor is connected Excessive voltage drops are occurs. Due to this the operation of other appliances connected to the line may be impaired & they may refuse to work, in particular cases.

The hard switching generates unsatisfactory dynamic behavior, creating sudden variations in the voltage and current of the motor parameters for this reason DC motor is starting using controller as a smooth starter. These problems can be solved by using Buck converters. Buck converter can allow the smooth start of a DC motor by applying the necessary voltage tracing under a required angular speed. In unusual, the DC-DC Buck converter has inductor and capacitor two energy storing elements that produce smooth DC output voltages and armature currents with a small current ripple, caused by the hard switching of the PWM reducing the noisy shape. Thus, to obtain the angular speed tracing work of the DC-DC Buck converter–DC motor system model. [1]

This paper is analyse speed control of separately excited DC motor establish on smooth starting tracing work. For the evaluation of control strategies a simulation environment is developed within simulink MATLAB. In this, dynamic model of the buck converter dc motor is derived. Resistance starting and one feedback control a strategy which is PI controller is developed in this simulation work. Performance

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of resistance starting and PI controller are examined in terms of angular velocity, duty cycle, armature voltage, armature current, electromagnetic torque. Finally, a comparison between resistance starter and PI controller on the system parameters performance are discussed and presented.

The literature regarding to DC-DC buck converters -DC motor system model is as follows. Carrying out the angular speed trajectory tracing work for the DC-DC power converter–DC motor system model is designed with the basis of for the proper variation called step less control. It is consist of a two control. The first control based on differential flatness and the second control uses a cascade controller applied to the buck converter to generate the voltage υ which is required by the DC motor [1]. For a buck converter-DC motor system model to be differentially flat with flat output the angular shaft velocity, which is assumed to be measured is based on a flatness controller. The flatness based controller obtained a better performance under a system parameters variations [2].A comparative evaluation of the performance of the PI and linear quadratic regulator controllers for the angular velocity tracking problem of a DC-DC Buck converter –DC motor system. The control design of a buck converter driven dc motor with Linear Quadratic Regulator (LQR) controller and Proportional-Integral (PI) controller are the techniques proposed in this investigation to control the speed of a dc motor. Performances of the controller are analysed in terms of angular velocity, duty cycle input energy and armature current. The angular velocity of buck converter driven dc motor can effectively be handled by both LQR and PI controller [3].The conceptions of active disturbance rejection control (ADRC) and flatness-based control are used to regulate the response of a DC-DC buck converter simulated by unknown, exogenous, time-varying load current demands. The generalized proportional integral controller is used to estimate and cancel the time-varying disturbance signals. A robust control technique based on ADRC& differential flatness [4].

II. MATHEMATICAL MODEL OF DC-DC BUCK CONVERTER WITH DC MOTOR

For domestic and industrial applications separately excited direct current motors are widely used. The speed control of a DC motor with high accuracy is essential. There are various types of DC motor are available. Depending upon type, a DC motor either controlled by changing the input current or changing the input voltage. Its good electrical and mechanical performances compared to other DC motor models hence in this, the separately excited DC motor system model is chosen. [5] The DC motor is driven by applied armature voltage. Fig.1 shows an equivalent model
Of DC-DC buck converter - separately excited DC motor.

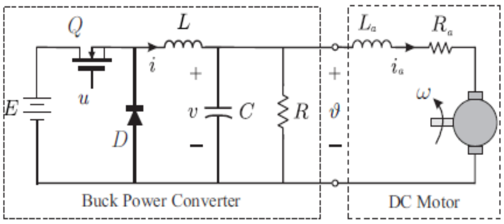

Fig. 1: equivalent circuit of DC-DC buck converter –DC motor model

The dynamics of a separately excited DC motor model may be expressed as

$$Va = Ra\ ia + La \frac{dia}{dt} + Eb \qquad (1)$$

$$Va = Ra\ ia + La \frac{dia}{dt} + Kb\ \omega$$

$$T = K_T\ ia = J\frac{d\omega}{dt} + B\omega \qquad (2)$$

Where,
Va = armature voltage (volt),
Eb = back emf (volt),
Ra = armature resistance (ohm),
La = armature inductance (H),
J = moment of inertia of the motor (kgm2/s2),
T = motor torque (Nm),
B = viscous friction coefficient (Nms),
KT =torque factor constant (Nm/A),
Kb = back emf constant (Vs/rad),
ω = angular speed (rad/s), and
ia = armature current (A).
Equations (1) and (2) are rearranged to obtain the state space system model of a separately excited DC motor

$$\frac{dia}{dt} = -\frac{Ra}{La}\ ia - \frac{Kb}{La}\omega + \frac{Va}{La} \qquad (3)$$

$$\frac{d\omega}{dt} = \frac{KT}{J}\ ia - \frac{B}{J}\omega \qquad (4)$$

Selecting the angular speed (ω) and armature current (ia) as state variables and the armature voltage (Va) as a input. The output is selected to be the angular speed.
Thus, Equations (3) and (4) can be expressed by,

$$\begin{bmatrix} \frac{di_a}{dt} \\ \frac{d\omega}{dt} \end{bmatrix} = \begin{bmatrix} i_a \\ \dot{\omega} \end{bmatrix} = \begin{bmatrix} \frac{-R_a}{L_a} & \frac{-K_b}{L_a} \\ \frac{K_T}{J} & \frac{-B}{J} \end{bmatrix} \begin{bmatrix} i_a \\ \omega \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{L_a} \end{bmatrix} V_a$$

$$y = \begin{bmatrix} 0 & 1 \end{bmatrix} \begin{bmatrix} i_a \\ \omega \end{bmatrix}$$

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III. IMPORTANCE OF SMOOTH STARTER

A motor smooth starter is a device used with DC electric motors for a short time to reduce the load and torque during of the motor start-up. This eliminates the mechanical stress on the motor and shaft, as well as the electrodynamics stresses on the connected power cables and electrical distribution network, increasing the lifespan of the system. [7]

ADVANTAGES

1. Reduced starting current and starting torque
2. Elimination of mechanical transients and electrical transients
3. Improving the life of motor.
4. Make the armature current of motor

IV. BASIC CONCEPT OF PROPORTIONAL INTEGRAL (PI) CONTROLLER

Presently, the Proportional Integral (PI) controller is mostly used in industrial utilisation because of its simple structure, easy design and low cost. Sometimes of these features when the controlled object is hugely nonlinear and uncertain the proportional integral (PI) controller is fails. Proportional integral (PI) controller minimizes the steady state error and reduces the effect of noise signal. In proportional integral controller the speed of response is a negative effect and complete stability of the system. Therefore, PI controller will not increase the response of speed. what will happen with the error in near future using PI controller does not have predicted but by using derivative control has ability to predict what will happen with the error signal in near future and thus to decrease a reaction time of the controller. In industry Proportional integral (PI) controllers are very commonly used, when speed of the response is not problem A proportional integral (PI) controller without Derivative controller is used when

1. Slow response of the system is obtained.
2. During operation of the process presents large noise and disturbances.
3. The system is used only, when one capacitive or inductive energy storage element present in process.
4. To obtained transport delays in the system is large.

Therefore, we like to maintain the features of the PI controller. A proportional integral (PI) controller use the proportional and integral gain is remains unchanged. This controller is called proportional integral controller or PI controller. [10, 12, 13]

V. SPECIFICATION OF THE DC-DC BUCK CONVERTER – SEPARATELY EXCITED DC MOTOR

Dc motor Armature side : P_0 = 1HP , Supply voltage =180 V (base value) , I_{am} = 5.1A (base value) , N = 1500 RPM(base value) , L_m = 111.6mH , R_m = 6.1 ohm , L_{af} = 3.44 H , J = 3.4 e-3 kg*m^2 , B = 2.7 e-3Nm/rad , Torque = 4.75 Nm(base value)

DC motor field side: R_f = 696.1 ohm, Lf = 25.023H, E_f = 180v

Buck converter: L = 2.769mH, Rated current = 6A, C = 440µF, Switching frequency =32 Khz, Dc supply voltage= 220 V [5]

A. DC MOTOR STARTING USING RESISTANCE STARTER

In this section, armature resistance starter are designed in MATLAB /simulink for DC motor starting using resistance starter. Initially when the rotor is at a rest the full resistances of the starter appears in series with armature winding is within safe limit. When the separately excited DC motor starts rotating back emf produce which take care of the armature current by reducing the net voltage in armature winding. Hence the starter is no more required.

Therefore, the starting resistances are cut off in steps with a specific delay time and finally no resistance of starter remains in the circuit and the rated voltage appears across the armature winding.[8]

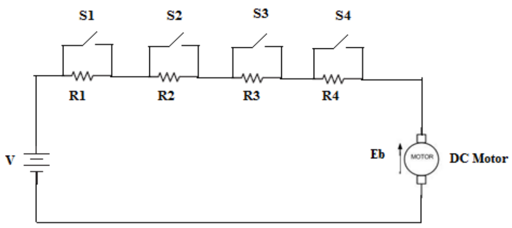

Fig. 2: Block diagram of DC motor using Resistance starting

VI. CONTROLLER DESIGN

In this section, PI controller is proposed and describe in detail. In this to maintain the limited speed of the DC motor controlling the duty pulses is the main objectives of the PI controller. In the closed loop system feedback PI controller are integrated in order to produce the control action lies in 0 and 1.

A. PI CONTROLLER

To illustrate, DC motor angular velocity can be controlled by controlling the performance of PI controller.[3] In DC motor The actual angular speed ω(s) is feedback and compared with the reference angular speed ωr(s) as shown in fig.3 .the required angular speed is obtained In terms of control the duty cycle δ(s), the error signal is generated and given to the buck converter -DC motor model through the proportional and integral gain, where it can be obtained as

$$\delta(s) = Gc(s)\,[\omega r(s) - \omega(s)]$$

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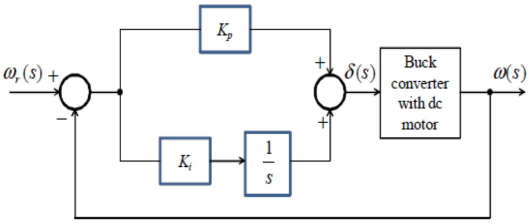

Fig. 3: Block diagram using PI control

The closed loop transfer function is given as

$$\text{C.L.T.F.} = \frac{\omega(s)}{\omega r(s)} = \frac{Gc(s)G(s)}{1+Gc(s)G(s)}$$

Where, $Gc(s) = Kp + \frac{Ki}{s}$ & $G(s) = \frac{\omega(s)}{\delta(s)}$

VII. SIMULATION RESULTS

In this, the entire model of a separately excited DC motor with resistance starting and DC-DC buck converter-DC motor with proportional integral controller was executed in MATLAB/Simulink. Simulation results of the PI controller were compared with resistance starting. By observing the Simulations result to judge whether the proportional integral controller is better than the resistance starting or not. At firstly, simulation model of Resistance starting circuit are executed in MATLAB and its corresponding results are presented and secondly, the simulation model of DC-DC buck converter -DC motor using PI controller circuit are executed in MATLAB and its corresponding results are presented.

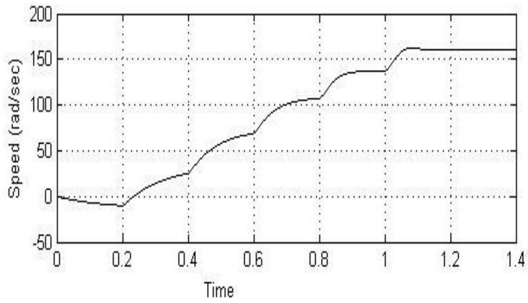

Fig. 4 : Simulation result of DC motor for speed(rad/sec) using resistance starting

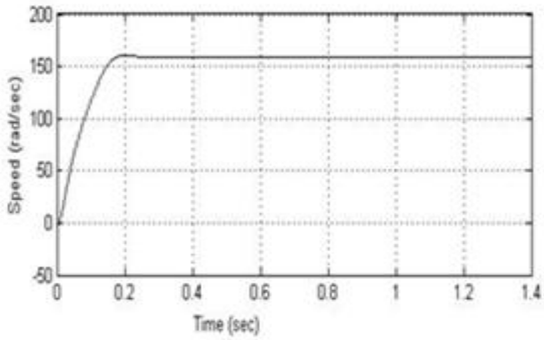

Fig. 5: Simulation result for speed (rad/sec) using PI controller

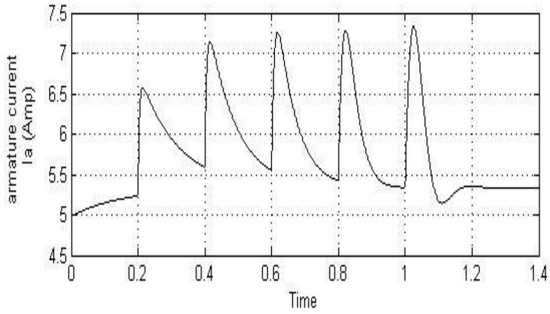

Fig. 6 : Simulation result of DC motor for armature current (Amp) using resistance starting

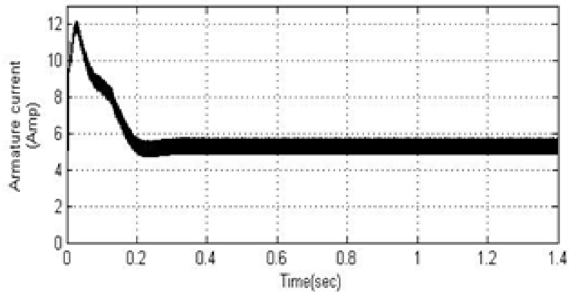

Fig. 7: Simulation result for armature current (Amp) using PI controller

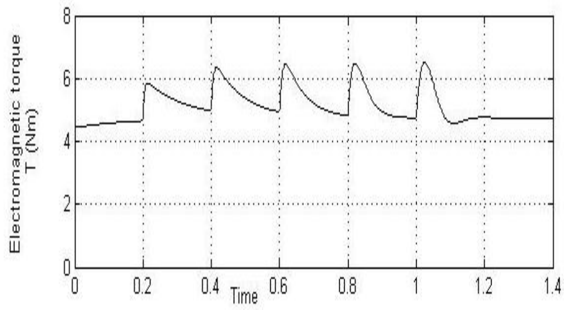

Fig. 8 : Simulation result of DC motor for electromagnetic torque (Nm) using resistance starting

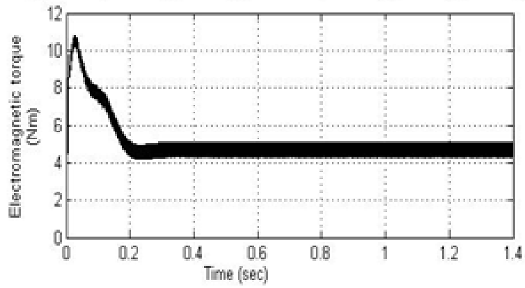

Fig. 9 : Simulation result for electromagnetic torque (Nm) using PI controller

In terms of duty pulses, DC-DC buck converter DC motor system are controlled

δ = Ton / Ton+ Toff

Duty cycle $\delta = 0.44$

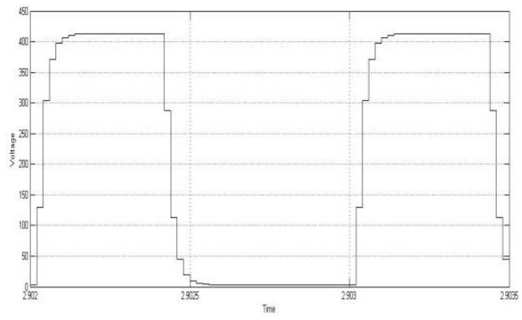

Fig. 10: Simulation result for voltage (volt) using PI controller

Starting performance of the resistance starting and DC-DC buck power converter-DC motor with PI controller are summarized in table 1. The system response namely angular speed, armature current and electromagnetic torque is observed. Simulations results which shows that the angular speed responses for resistance starting and proportional controller (PI) when a separately excited DC motor operating at a reference speed from 0 to 158.07 rad/sec. The angular speed response reaches the required speed from 0 to 158.07 rad/sec is shown, it is observed that the proportional integral controller (PI) are better capable in tracing the required input. In this PI controller is the smallest value of settling time which is observed the high speed input tracing response. The rated armature current of a separately excited DC motor is 5.7 amp and the starting armature current of a separately excited DC motor in PI controller is 12 amp. By the PI controller simulation result observed that the starting electromagnetic torque is 10.8 Nm and the rated electromagnetic torque is 4.9Nm nearly same as the calculated result. It is observed that the for smooth starting PI controller is better than the resistance starting.

VIII. RESULT

Table 1: Comparison between DC-DC Buck converter-Separately Excited DC motor system

Sr. no.	parameters	Resistance starting	PI controller
1	Speed(rad/sec)	160	158.2
2	Starting armature current (amp)	7.33	12
3	Starting electromagnetic torque (Nm)	6.52	10.8
4	Settling time(sec)	1.104	0.16

IX. CONCLUSION

Analysis into smooth starting of DC-DC buck converter-DC motor system by using proportional integral (PI) controller is presented. Simulation result observe that the better Performance of proportional integral controller (PI) by tracing the required speed. PI controller is explained in terms of parameters duty cycle, angular velocity, armature voltage, armature current and electromagnetic torque. The results show that by using the PI controller angular velocity of the DC-DC buck converter - DC motor can be successfully control. In PI controller is the smallest value of settling time, which is observed the high speed input tracking response.

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