International Journal of Electronics and Electrical Engineering

Volume 3 | Issue 2 Article 4

October 2014

AN ALGORITHM FOR THE ANALYSIS OF TRANSIENT AND STEADY STATES IN A DC MOTOR

S.V.M.B. PRABHATH KIRAN
Department of Electrical Engineering, National Institute of Technology, Kurukshetra, Haryana, India, prabhathsurampudi@gmail.com

ANIL BHARADWAJ CHIVUKULA
Department of Electrical Engineering, National Institute of Technology, Kurukshetra, Haryana, India, anil001.eee@gmail.com

Follow this and additional works at: https://www.interscience.in/ijeee

Part of the Power and Energy Commons

Recommended Citation
KIRAN, S.V.M.B. PRABHATH and CHIVUKULA, ANIL BHARADWAJ (2014) "AN ALGORITHM FOR THE ANALYSIS OF TRANSIENT AND STEADY STATES IN A DC MOTOR," *International Journal of Electronics and Electical Engineering*: Vol. 3 : Iss. 2 , Article 4.
DOI: 10.47893/IJEEE.2014.1134
Available at: https://www.interscience.in/ijeee/vol3/iss2/4

This Article is brought to you for free and open access by the Interscience Journals at Interscience Research Network. It has been accepted for inclusion in International Journal of Electronics and Electical Engineering by an authorized editor of Interscience Research Network. For more information, please contact sritampatnaik@gmail.com.

AN ALGORITHM FOR THE ANALYSIS OF TRANSIENT AND STEADY STATES IN A DC MOTOR

S.V.M.B.PRABHATH KIRAN, CH.ANIL BHARADWAJ

M.Tech Scholar, Department of Electrical Engineering, National Institute of Technology, Kurukshetra, Haryana, India.
Email: prabhathsurampudi@gmail.com, anil001.eee@gmail.com

Abstract—Braking is one of the important operations in electric drives. Due to their friendly speed torque characteristics, DC motors are still in domination for industrial applications. In this paper an attempt has been made to develop a systematic algorithm for determining braking time of DC motor during Dynamic braking. With this algorithm braking time of the motor can be estimated so that more accurate simulation of the DC motor may be obtained.

Keywords*-Second order model, Dynamic Braking, DC motor.*

I. INTRODUCTION

Till to date DC motors are dominant in many industrial applications due to their user friendly torque speed characteristics. They are being used as the main source of mechanical energy. Any drive system mainly consists of the following major components,

1. Electric source
2. Power modulator
3. Electric motor and
4. A mechanism to produce the mechanical energy according to the requirement.

For any drive system, along with its speed control, there is also a need for its braking. In case of Mine Hoists, Traction etc braking is the major operation that is frequently employed.

Due to its ease of operation and less cost Mechanical braking is normally used for braking Electric drives. But this type of braking is not much preferred due to its less efficiency, under heavy load conditions and its unreliability. It posses the following disadvantages,

i) It requires frequent maintenance and replacement of the brake shoes,
ii)Braking power is wasted as heat.

In order to improve reliability in braking, Electrical braking is more preferred. Much preferably Dynamic braking or Regenerative braking is employed [1], The references [2], [3] considered only the behavior of motor energized by either a Chopper or a Converter during braking. But in case of traction and Mine winders motors should be stopped in specified time to improve its overall performance. For obtaining such performance it is mandatory to have thorough knowledge on the behavior of that motor during dynamic braking. Hence the motor has to be completely analyzed in all conditions including the Braking. The analysis of the drive may be mathematical, dealing with the known constraints and mathematical model of the motor under consideration.

The results thus obtained can help in getting a clear knowledge about the whole system of the drive, under regular and abnormal operating conditions. The algorithm mentioned may be used for any motor. For validating the results, they are compared with the practical results obtained for the motor during normal operation and braking modes.

II. MATHEMATICAL MODEL

A. Second order model of DC motor

Analysis of a DC motor can be done using the first order and second order models of DC motor. Eq. (1) & (2) are the first order differential equations of a DC motor. Braking operation analysis is made by using these first order equations. These equations when analyzed and solved give unacceptable error, showing large difference between practical and theoretical results. Hence to improve accuracy, second order model of DC motor is preferred. Fig. 1 shows basic circuit for separately excited DC motor.

$$V_a=R_ai_a+L_api_a+K_b\omega_m \quad (1)$$

$$K_mi_a=T_L+J_ap\omega_m+B\omega_m \quad (2)$$

The Eqs. (1) & (2) give the armature current and speed of motor during any transient as well as steady state operations. The Second order equations for the DC motor can be obtained using the equations (1) & (2). The step-by-step procedure for obtaining the second order equations is given below.

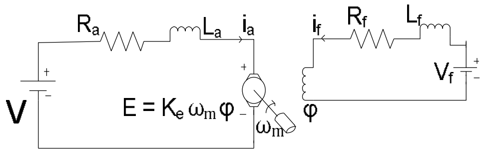

Fig.1. Representation of separately DC motor

Initially differentiate (1) which yields

$$pV_a = R_a i_a + L_a p^2 i_a + K_b p\omega_m \quad (3)$$

Substitute (2) in (3) in place of $p\omega_m$, this gives second order differential equation in terms of armature current. After rearranging terms, we have,

$$pi_a^2 + (1 + \tau a/\tau_{m1})\, pi_a + i_a/\tau_{m2} = K_2/\tau_{m2} \quad (4)$$

In the same way differentiate (2) ,

$$K_m pi_a = pT_L + J_m p^2\omega_m + Bp\omega_m \quad (5)$$

using (1), makes the total equation, interms of speed. Also assuming Load Torque (T_L) constant makes 'pT_L', zero. The Second order equation for speed is,

$$\tau_a p^2\omega_m + (1 + \tau a/\tau_{m1})\, p\omega_m + i_a/\tau_{m2} = K_1/\tau_{m2} \quad (6)$$

The eqs. (4) & (6) represent the second order differential equations of the DC motor. To know the response, these equations are to be solved with the help of any ODE or Numerical Differentiation technique.

B. Dynamic Braking of DC motor

Dynamic Braking is the most preferred braking mechanism for DC motor. Among all the other methods dynamic braking is mostly employed because of its simplicity when compared with Regenerative braking. The Regenerative Braking can be applied only when certain constraints are met. The other technique Plugging causes excessive flow of current, through armature winding in short span of time, which may causes damage to the armature winding. Due to these disadvantages the methods other than dynamic Braking are not much preferred.

In Dynamic braking, at the instance of application of brake the armature terminals are disconnected from supply and are connected across some external resistance, with field winding still energized. This makes motor to act as a generator and the total kinetic energy stored in rotating parts is dissipated as heat in the external resistance connected across the armature, braking the motor. Circuit set up for the dynamic braking is as shown in Fig. 2.

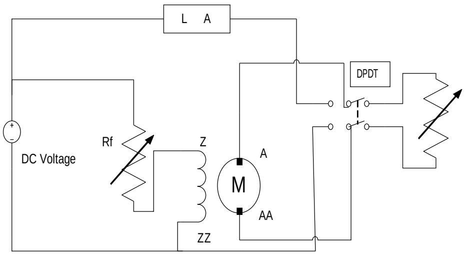

Fig.2. Circuit set up for Dynamic braking of DC motor

Amount of Kinetic energy stored in rotating parts of DC motor is,

$$\text{Energy stored} = 0.5J_m\omega_m^2 \quad (7)$$

Hence electrical energy dissipated in external resistance is

$$\text{Electrical energy} = [E_b^2/(R_a+R_{ext})]*t_b \quad (8)$$

Form Law of conservation of energy Eq. (7) must be equal to Eq. (8) this gives the value of external resistance to be added for required braking time. It is given by the Eq. (9),

$$R_{ext} = [(0.5J_m\omega_m^2) / (E_b^2*t_b)] - R_a \quad (9)$$

III. ALGORITHM FOR BRAKING TIME

The following algorithm gives the steps for determining braking time of DC motor with dynamic braking. Following this algorithm we can theoretically determine the time of braking of motor at any loaded condition. In this algorithm DC motor is analyzed with help of second order model. But conventional methods available are only able to solve first order differential equations. Hence the obtained second order equations are transformed to two first order equations [4]. This yields two sets of two first order differential equations where one relates to armature current and other for speed.

- Step.1: Initiate the program to find braking time of DC motor.
  Step.2: Read parameters of DC motor and its loading condition.
- Step.3: Read operating time of motor, instant of braking to be applied on motor.
- Step.4: Calculate required braking resistance by using (9).
- Step.5: Initialize time to zero and start a loop.
- Step.6: Solve differential equations using any method like Euler's method etc.
- Step.7: Store the results to display.
- Step.8: Increment time by step value and check whether time equal to braking instant. If condition satisfies go to Step.9 else go to step.6.
- Step.9: Change conditions such machine is under Dynamic braking condition. Hence make applied voltage to zero and armature resistance equal to value obtained in Step.4.
- Step.10: Solve differential equations using any method like Euler's method etc.
- Step.11: Store results for display
- Step.12: Check whether armature current equals to zero. If condition satisfies store

time instant and go to step.15 else go to step.13.

- Step.13: Check whether motor speed becomes zero if condition satisfies store instant of time and go to step.15 else go to step.14.
- Step.14: Increment time by step value and check whether time equal to final time. If condition satisfies go to Step.15 else go to step.10.
- Step.15: Measure braking time of DC motor by subtracting applied braking instant form time obtained in Step.14 and store result obtained.
- Step.16: Plot response of armature current and speed with respect to time.
- Step.17: Display braking time taken by motor.
- Step.18: Stop the program.

IV. COMPUTED AND EXPERIMENTAL RESULTS

Using the proposed algorithm braking time is determined on DC motor generator set. Table I and II give typical comparison of braking time obtained by the proposed algorithm and experimental result for Machine-1, Table III and TABLE IV for Machine-2. Fig.3 gives response of motor when analyzed with second order model under normal operation and dynamic braking. With the identical results obtained by the using proposed algorithm and practical tests, it can be inferred that the proposed algorithm gives braking time of DC motor precisely.

The accurate determination of the Braking time, improves the accuracy of the machine models and also helps in their improvisation.

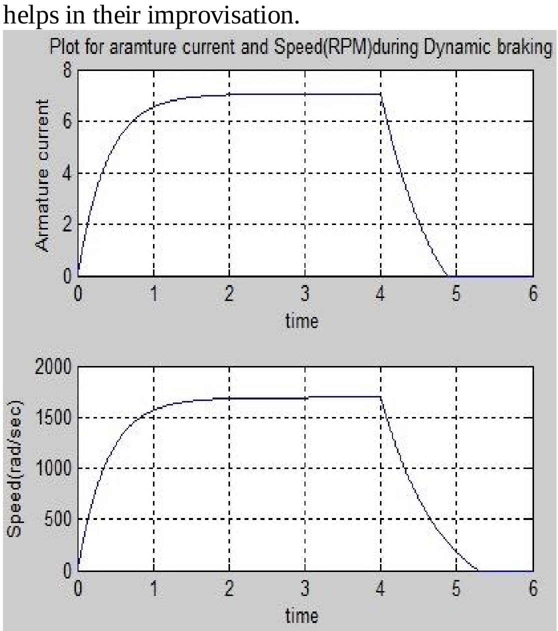

Fig.3. Response of DC motor during normal operation for t=0 to 4 sec and dynamic braking from t=4 to t=6 with half of rated load

TABLE I. TABLE FOR BRAKING TIME AT FULL LOAD FOR MACHINE-1

S.No	Resistance(Ω)	Practical time (sec)	Determined time(sec)
1.	20	0.624	0.63
2.	40	0.763	0.76
3.	60	0.956	0.94
4.	80	1.343	1.32

TABLE II. TABLE FOR BRAKING TIME AT ONE-FOURTH LOAD FOR MACHINE-1

S.No	Resistance(Ω)	Practical time (sec)	Determined time(sec)
1.	20	0.79	0.75
2.	40	0.95	0.89
3.	60	1.44	1.5
4.	80	1.76	1.72

TABLE III. TABLE FOR BRAKING TIME AT NO-LOAD CONDITION FOR MACHINE-2

S.No	Resistance(Ω)	Practical time (sec)	Determined time(sec)
1.	20	2.4	2.221
2.	40	2.9	2.885
3.	60	2.8	2.909
4.	80	3.6	3.589

TABLE IV. TABLE FOR BRAKING TIME AT ONE-FOURTH LOAD FOR MACHINE-2

S.No	Resistance(Ω)	Practical time (sec)	Determined time(sec)
1.	10	0.79	0.805
2.	20	1.75	1.735
3.	30	2	2.015
4.	40	2.3	2.305

V. CONCLUSION

An algorithm for determining braking time of DC motor during dynamic braking has been proposed. The experimentally obtained results agree with the predicted results by the algorithm, in both loaded and no load conditions. Hence this algorithm can be used in determining braking time of DC motor with dynamic braking.

REFERENCES

[1] Thomas D.Barkan, William J.Helfrich "Application of Dynamic braking to Mine Hoisting systems," IEEE Transc.on Industrail.App. vol. 24, pp. 884–896,September 1988

[2] Sailendra N Bhadra, Nisit K De, Ajit K Chattopadhyay "Regenarative Braking Performance Analysis of a Thyristor Chopper Contolled DC Series Motor," IEEE Transc.on Industrail.Elec & Cont.Instrumentation. vol. 28, pp. 342–347,November 1981

[3] Paresh C Sen, Murray L McDonald "Thyristorised DC Drives with Regenarative Braking and Speed Reversal," IEEE Transc.on Industrail.Elec & Cont.Instrumentation.vol.27,pp 347–354,November 1978.

[4] "MATLAB help for Using ODE45," Bucknell University.

NOMENCLATURE

V_a	Armature voltage
i_a	Armature current
R_a	Armature resistance
L_a	Armature inductance
J_m	Combined moment of inertia of motor generator set
B	Co-efficient of Friction
K_b	Back emf constant
K_m	Torque constant
ω_m	Speed of motor
p	d/dt (differential operator)
τ_a	Electrical time constant of DC motor
τ_{m1}	Mechanical time constant of DC motor
T_L	Load torque

APPENDIX

By substituting (2) in (3) instead of $p\omega_m$ it gives

$$0=R_ai_a+L_api_a^2+(K_b/J)[K_mi_a-B\omega_m] \quad (8)$$

in (8) put (1) for ω_m

$$L_api_a^2+R_api_a+(K_bK_mi_a)/J+(L_a/\tau_{m1})pi_a+(R_aB/J)i_a = (BV_a+K_bT_L)/J_m$$

further simplifying above equation by dividing both sides with R_a,

$$(L_a/R_a)pi_a^2+(1+La/R_a\tau_{m1})pi_a+i_a(K_bK_m+BR_a)/J_mRa+i_a/\tau_{m1} = (BV_a+K_bT_L)/J_mR_a \quad (9)$$

$$\tau_api_a^2+(1+\tau a/\tau_{m1})pi_a+i_a/\tau_{m2}=K_2/\tau_{m2}$$

where $\tau_a=(L_a/R_a)$, $\tau_{m1}=(J_m/B)$, $\tau_{m2}=(J_mR_a)/[BV_a+K_bT_L]$

In similar way substituting (1) in (5) for pi_a which yields

$$(K_m/L_a)[V_a-R_ai_a-B\omega_m]=pT_L+J_mp^2\omega_m+B\omega_m \quad (10)$$

from (2) replace i_a in (10)

$$K_mV_a/L_a - R_aT_L/L_a - (JR_a/L_a)p\omega_m - (BR_a/L_a)\omega_m-(K_mK_b/L_a)\omega_m =J_mp^2\omega_m+Bp\omega_m \quad (11)$$

by re arranging all the above terms

$$\tau_ap^2\omega_m+(1+\tau a/\tau_{m1})p\omega_m+i_a/\tau_{m2}=K_1/\tau_{m2}$$

where $K_1=(KmV_a-T_LR_a)/J_mR_a$

Machine Parameters

Parameter	Machine 1	Machine 2
V_a	220V	V_a=220V
R_a	3.68Ω	4.25Ω
L_a	28.2716mH	20.2716mH
J_m	0.25gcm^2	0.1 gcm^2
Rated current	13A	13A
B	0.005	0.005
K_b	1.0960	1.0488
K_m	1.4691	1.4691

DC Generator

Parameter	Values
V_a	220V
R_a	3.68Ω
L_a	28.2716mH
Rated current	13A
B	0.005

◈◈◈