Parameter Identification Of A DC Motor

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Abstract: This paper presents three different simple techniques for the parameter identification of DC motor. In day to day life DC-motors are used in a wide variety of applications Most of the motors is attended by a large amount of time and resources devoted to inspecting them at the end of their production cycle. Due to the increasing mass production of these motors, procedures for inspecting them have been developed which are able to deter-mine the test objects characteristic curves within seconds. Such procedures are known as Parameter Identification procedures. They determine the parameters without applying any external load, simply by measuring the current and speed. First the motor is simulated with the known parameters using the dynamic equation in MATLAB. Using the three simple techniques the parameters are identified and the advantages and disadvantages of each method is discussed.

Index Terms : Analytical equation, Current response, Error calculation, estimated parameters, MATLAB, Mathematical model, Regression method, Speed response.

1. INTRODUCTION

DC motors have wide applications in industrial control systems because they are easy to control and model. For analytical control system design and optimization, sometimes a precise model of the DC motor used in a control system may be needed. In this case, the values for reference of the motor parameters given in the motor specifications, usually provided by the motor manufacturer, may not be considered adequate, especially for cheaper DC motors which tend to have relatively large tolerances in their electrical and mechanical parameters. Study of an electromechanical system is carried out by identifying the mechanical and electrical parameters of the motor from mathematical modelling and simulation in [1]. The variables and parameters in mechanical equations of separately excited DC motors are expressed in terms of electrical variables and parameters. The parameter is identified from the exact electrical equivalent circuit related to the whole electromechanical system of DC motor [2].This method is applied to identify the parametric model of a real experimental platform and of a simulated model [3].The major in parameter identification and is and Of a simulated model discussed in [4]. BLDC motor parameters are estimated with trial and error method and modeling and speed control of BLDC motor with hysteresis current controller is done using motor parameters which are estimated.

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Appropriate and effective estimation methods are chosen and are applied for the parameter estimation of BLDC motor. Speed control obtained with the estimated parameters of each method is simulated. Speed control of the motor with different estimation methods is compared [5] the values forreference of the motor parameters given in motor specifications provided by the motor manufacturer may not be considered adequate, especially for cheaper dc motors which tend to have relatively large tolerances in their electrical and mechanical parameters [6].Experiments to find the parameters of the brushless direct current motors are done to determine important constants for obtaining the motor transfer function, and the efficiency and performance motor curves [7]. In this paper the current and speed curve is obtained by simulating the mathematical model of the DC motor. A three simple techniques are used, (i) parameter estimation for different load condition (ii) by changing excitation voltage (iii) by using regression method. The estimated parameters are compared with the parameters used for simulation and the error is calculated in each method. The advantages and disadvantages of these methods are discussed.

2. MATHEMATICAL MODEL

Dynamic equation of dc motor is given in equations (1) and (2),

Electrical Equation is,

$$V = iR + L\frac{di}{dt} + K_b\omega \quad (1)$$

Where V is the terminal voltage, R is the resistance, L is the inductance, i is the current, K_b is the back emf constant and ω is the speed.

Mechanical Equation is,

$$K_b i = J\frac{d\omega}{dt} + B\omega + T_L \quad (2)$$

Where K_b is the back emf constant, i is the current, J is the moment of inertia, B is the co-efficient of friction and T_L is the load torque.

Using the dynamic equations, the current and speed curve of the dc motor is simulated using MATLAB. The motor parameters in table 1 is used to obtain the current and the speed curve and is shown in fig.2 and fig.3.

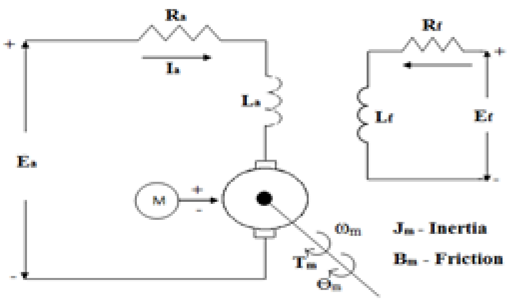

Fig 1. *Equivalent Circuit of DC Motor*

Table 1
Motor parameters

MOTOR PARAMETERS	ORIGINAL VALUES
R	0.5Ω
L	1.5mH
J	$0.00025Kgm^2$
B	0.0001Nm/rad/s
K_b	0.05volts/RPM
K_t	0.05Nm/A

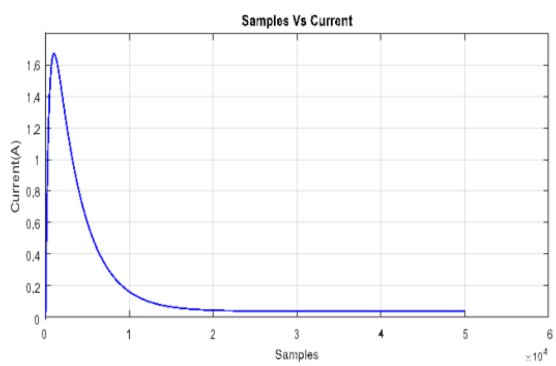

***Fig 2**. Current response for sampling interval of 1ms*

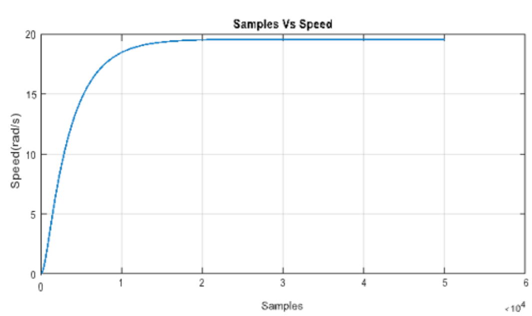

***Fig 3**. Speed response for sampling interval of 1ms*

Using the current and speed responses, the variables shown in table II are measured for parameter identification. Table II also gives the parameters to be estimated using different techniques. The measured values are shown in Fig.4 and Fig.5.

Table 2
Measured variables and Estimated parameters

MEASURED VARIABLES	ESTIMATED PARAMETERS
i_m i_∞ ω_m ω_∞ t_p t_1, t_2 i_1, i_2 ω_1, ω_2	K (Nm/A) R (Ω) B (Nms/rad) L (H) J (Kgm^2)

where i_m = maximum current, i_∞ = steady state current, ω_m =maximum speed, ω_∞= steady state speed, T_L =load torque, i_1, i_2= current 1 and current 2 at time 1 and time 2, ω_1, ω_2 = speed 1 and speed 2 at time 1 and time 2.

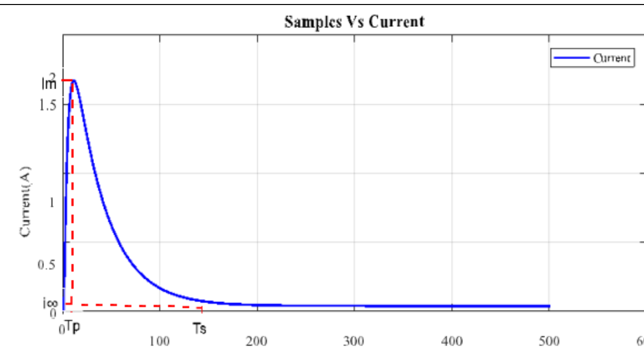

***Fig 4**. Measured variables in current response*

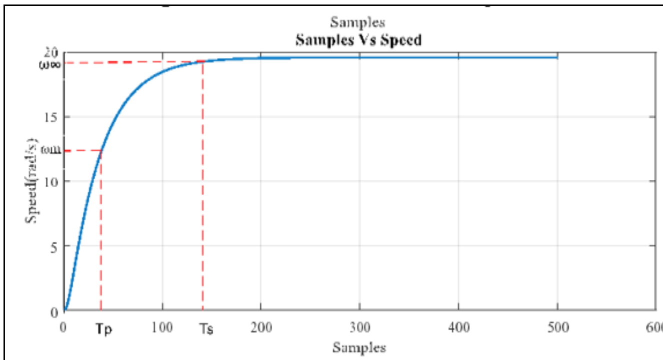

Fig 5. *Measured variables in speed response*

3. ANALYTICAL EQUATION BASED PARAMETER IDENTIFICATION

The steady state speed equation is obtained from [3],

$$\frac{\omega(s)}{V(s)} = \frac{1/K_b}{t_m t_e s^2 + t_m s + 1} \quad (3)$$

$$\omega_\infty = \frac{V}{K} \quad (4)$$

$$K = \frac{V}{\omega_\infty} \quad (5)$$

By using the dynamic equation (1),

At peak time, $\frac{di}{dt} = 0$

$$V = i_m R + K\omega_m \quad (6)$$

$$R = \frac{V - K\omega_m}{i_m} \quad (7)$$

From equation (1) and (2),

Current equation is,

$$I(s) = \frac{(J_s + B)V(s) - kt}{(R + Ls)(Js + B) + K^2} \quad (8)$$

At steady state condition,

$$i_\infty = \frac{BV - KT}{RB + K^2} \quad (9)$$

By rearranging the above equation,

$$B = \frac{K^2 i_\infty + KT}{V - Ri_\infty} \quad (10)$$

$$L\frac{di}{dt} = V - iR - k\omega \quad (11)$$

Rearranging the equation (1),

$$L = \frac{V - i_1 R - K\omega_1}{\frac{i_2 - i_1}{t_2 - t_1}} \quad (12)$$

Rearranging the equation (2),

$$J\frac{d\omega}{dt} = k_i - B_\omega - T_L \quad (13)$$

$$J = \frac{Ki - B\omega - T}{\frac{\omega_2 - \omega_1}{t_2 - t_1}} \quad (14)$$

The dc motor parameters are estimated using the equations (5), (7), (10), (12) and (14). The parameters are estimated under two conditions,

At V=1V,

Without load,

Case (i) T_L=0, B=0.0001Nm/rad/s

Case (ii) T_L=0, B=0

With load,

Case (iii) T_L=0.01Nm, B=0

Case (iv) T_L=0.01Nm, B=0.0001Nm/rad/s

The above cases are analyzed at same sampling intervals to estimate the motor parameters for all the cases.

3.1 Case (i) T_L =0, B=0.0001Nm/rad/s

For load torque, T_L = 0 and friction co-efficient, B= 0.0001Nm/rad/s the motor parameters is estimated for same sampling interval in table 3.

3.2 Case (ii) T_L=0, B=0

Parameter estimation is also done under no load condition. Similar to the previous case error is calculated from the measured and estimated values under no load condition and is given in table 4.

3.3 Case (iii) T_L =0.01Nm, B=0

For load torque, T =0.01Nm and frictional coefficient, B=0 the motor parameters is estimated in table 5.

L

3.4 Case (iv) T_L =0.01Nm, B=0.0001Nm/rad

For load torque, T= 0.01Nm and frictional coefficient, B=0.0001Nm/rad the motor parameters is estimated in table 6.

Table 3

Parameter estimation for T_L =0, B=0.0001Nm/rad/s

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2											
MEASURED VARIABLES							ESTIMATED PARAMETERS				
	t (ms)		I (A)		ω (rad/s)		K (Nm/A)	R (Ω)	B (Nms/rad)	L (mH)	J (Kgm^2)
i_m=1.7544A i_∞=0.0392A ω_m=2.37rad/s ω_∞=19.6rad/s t_p=9ms	t_1	1.03	i_1	0.6	ω_1	0.07				1.90	1.940e^{-4}
	t_2	2.11	i_2	1.0	ω_2	0.24					
	t_1	1.58	i_1	0.8	ω_1	0.15				1.83	2.03e^{-4}
	t_2	2.81	i_2	1.2	ω_2	0.39					
	t_1	2.11	i_1	1.0	ω_1	0.24	0.05	0.5	1.940e^{-4}	2.00	2.07e^{-4}
	t_2	3.75	i_2	1.4	ω_2	0.64					
	t_1	3.75	i_1	1.4	ω_1	0.64				2.00	2.39e^{-4}
	t_2	5.24	i_2	1.6	ω_2	1.08					

Table 4

Parameter estimation for T_L =0, B=0

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2											
MEASURED VARIABLES							ESTIMATED PARAMETERS				
	t (ms)		I (A)		ω (rad/s)		K (Nm/A)	R (Ω)	B (Nms/rad)	L (mH)	J (Kgm^2)
i_m=1.7544A i_∞=5.2502e^{-5}A ω_m=2.37rad/s ω_∞=19.6rad/s t_p=9ms	t_1	1.58	i_1	0.8	ω_1	0.15				1.83	2.00e^{-4}
	t_2	2.81	i_2	1.2	ω_2	0.39					
	t_1	2.11	i_1	1.0	ω_1	0.24				2.00	2.61e^{-4}
	t_2	3.75	i_2	1.4	ω_2	0.64					
	t_1	3.75	i_1	1.4	ω_1	0.64				3.46	2.34e^{-4}
	t_2	4.29	i_2	1.6	ω_2	1.08	0.05	0.5	0		
	t_1	4.29	i_1	1.6	ω_1	1.25				4.16	2.94e^{-4}
	t_2	6.24	i_2	1.8	ω_2	1.4					

Table 5

Parameter estimation for T_L =0.01, B=0

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2											
MEASURED VARIABLES							ESTIMATED PARAMETERS				
	t (ms)		I (A)		ω (rad/s)		K (Nm/A)	R (Ω)	B (Nms/rad)	L (mH)	J (Kgm^2)
i_m=1.7786A i_∞=0.2A ω_m=2.347rad/s ω_∞=17.99rad/s t_p=0.01s	t_1	2.10	i_1	1.0	ω_1	0.15				1.60	2.471e^{-4}
	t_2	1.20	i_2	1.2	ω_2	0.28					
	t_1	1.57	i_1	0.8	ω_1	0.08				1.60	2.615e^{-4}
	t_2	2.10	i_2	1.0	ω_2	0.15					
	t_1	1.32	i_1	0.7	ω_1	0.05				1.60	2.508e^{-4}
	t_2	1.82	i_2	0.9	ω_2	0.11	0.055	0.48	0		
	t_1	0.88	i_1	0.5	ω_1	0.01				1.70	1.938e^{-4}
	t_2	1.32	i_2	0.7	ω_2	0.05					

Table 6

Parameter estimation for T_L=0.01Nm, B=0.0001Nm/rad

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2											
MEASURED VARIABLES							ESTIMATED PARAMETERS				
	t (ms)		I (A)		ω (rad/s)		K (Nm/A)	R (Ω)	B (Nms/rad)	L (mH)	J (Kgm^2)
i_m=1.7788A i_∞=0.2353A ω_m=2.44rad/s ω_∞=17.6rad/s t_p=0.01ms	t_1	2.10	i_1	1.0	ω_1	0.15	0.05	0.48	1.5e^{-4}	1.8	2.507e^{-4}
	t_2	2.80	i_2	1.2	ω_2	0.28					
	t_1	1.57	i_1	0.8	ω_1	0.08				1.3	3.593e^{-4}
	t_2	2.10	i_2	1.0	ω_2	0.15					
	t_1	1.32	i_1	0.7	ω_1	0.05				1.7	2.568e^{-4}
	t_2	1.82	i_2	0.9	ω_2	0.11					
	t_1	1.08	i_1	0.6	ω_1	0.02				1.7	2.076e^{-4}
	t_2	1.57	i_2	0.8	ω_2	0.08					

3.5 ERROR CALCULATION

The error of estimated values is calculated using following equation (15)

Using the measured and the estimated values, the error is calculated and compared for all the sampling interval as given in table VII.

$$\text{Error} = \frac{\textbf{Calculated value} - \textbf{Estimated value}}{\textbf{Estimated value}} \ (\%) \quad (15)$$

T is the sampling interval,
Est val is the estimated value,
Error is the err.

From Table 10. It is found that under T_L=0.01Nm, B=0.0001Nm/rad/s gives minimum error value for K=0.05Nm/A, R=0.5Ω, B=0.0001Nms/rad.

Table 7

Error calculation for T_L =0, B=0.0001Nm/rad/s

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2												
Condition	t (ms)		K (Nm/A)		R (Ω)		B (Nms/rad)		L (mH)		J (Kgm^2)	
T_L =0 B=1e^{-4}Nms/rad step interval=1e^{-3}s	t_1	t_1	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR
	1.03	2.11	0.05	0	0.5	0	1.047e^{-4}	4.4	1.9	21.0	1.940e^{-4}	28.8
	1.58	2.87							1.83	18.0	2.03e^{-4}	18.8
	2.11	3.75							2.00	25	2.07e^{-4}	20.7
	3.75	5.20							2.00	25	2.39e^{-4}	4.60

Table 8

Error calculation for T_L =0, B=0

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2												
Condition	t (ms)		K (Nm/A)		R (Ω)		B (Nms/rad)		L (mH)		J (Kgm^2)	
T_L =0 B=0 step interval=1e^{-3}s	t_1	t_1	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR
	1.58	2.81	0.05	0	0.5	0	0	0	1.83	18.0	2.00e^{-4}	25
	2.11	3.75							2.00	2.5	2.61e^{-4}	4.21
	3.75	3.75							3.46	56.6	2.34e^{-4}	6.83
	4.09	6.02							3.33	55.23	2.33e^{-4}	5.23

Table 9

Error calculation for T_L =0.01 B=0

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=$1e^{-4}$Nms/rad, L=1.5mH, J=$2.5e^{-4}$Kgm^2												
Condition	t (ms)		K (Nm/A)		R (Ω)		B (Nms/rad)		L (mH)		J (Kgm^2)	
T_L =0.01Nm B=0 step interval=$1e^{-3}$s	t_1	t_1	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR
	2.10	1.20	0.055	0.9	0.48	4.1	0	0	1.60	6.2	$2.47e^{-4}$	1.17
	1.57	2.10							1.60	6.2	$2.61e^{-4}$	4.3
	1.32	1.82							1.60	6.2	$2.50e^{-4}$	0.3
	0.88	1.32							1.70	11.7	$1.93e^{-4}$	28.9

Table 10

Error calculation for T_L =0.01,B=0.0001Nm/rad/s

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=$1e^{-4}$Nms/rad, L=1.5mH, J=$2.5e^{-4}$Kgm^2												
Condition	t (ms)		K (Nm/A)		R (Ω)		B (Nms/rad)		L (mH)		J (Kgm^2)	
T_L =0.01Nm B=$1e^{-4}$Nms/rad step interval=$1e^{-3}$s	t_1	t_1	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR
	2.10	2.80	0.05	0	0.48	4.1	0	0	1.8	16.6	$2.507e^{-4}$	0.27
	1.57	2.10							1.3	15.3	$3.593e^{-4}$	30.4
	1.32	1.82							1.7	11.7	$2.586e^{-4}$	2.6
	1.08	1.57							1.7	11.7	$2.076e^{-4}$	20.4

4. PARAMETER IDENTIFICATION FOR VARIOUS VOLTAGE CONDITION

To estimate the parameter under following cases,

- Case (i) V=100V, B=0.0001Nm/rad/s,T=0.01Nm
- Case (ii) V=50V, B=0.0001Nm/rad/s, T=0.01Nm
- Case (iii) V=25V, B=0.0001Nm/rad/s, T=0.01Nm

4.1 Case (i) V=100V, B=0.0001Nm/rad/s, T=0

Dynamic equation of a dc motor is simulated under the voltage of V=100V at various sampling interval to obtain the characteristic curve of the speed and current. Using this curve, motor parameters are estimated.

4.2 Case (ii) V=50V, B=0.0001Nm/rad/s, T=0

Dynamic equation of a dc motor is simulated under the voltage of V=50V at various sampling interval to obtain the characteristic curve of speed and current. Using this curve, motor parameters are estimated.

4.3 Case (iii) V=25V, B=0.0001Nm/rad/s, T=0

Dynamic equation of a dc motor is simulated under the voltage of V=25 at various sampling interval to obtain the characteristic curve of speed and current. Using this curve, motor parameters are estimate and find the minimum error using Equation 15.

Table 11

Parameter estimation for 100V

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=$1e^{-4}$Nms/rad, L=1.5mH, J=$2.5e^{-4}$Kgm^2											
MEASURED VARIABLES							ESTIMATED PARAMETERS				
	t (ms)		I (A)		ω (rad/s)		K (Nm/A)	R (Ω)	B (Nms/rad)	L (mH)	J (Kgm^2)
T_L=0 B=$1e^{-4}$Nms/rad step interval=$1e^{-3}$s	t_1	2.10	i_1	15.2	ω_1	1889	0.05	0.5	$1e^{-4}$	1.02	2.23
	t_2	2.80	i_2	10.01	ω_2	1992					
	t_1	1.57	i_1	18.27	ω_1	1876				1.25	2.46
	t_2	2.10	i_2	15.2	ω_2	1889					
	t_1	1.32	i_1	33.28	ω_1	1862				1.55	2.52
	t_2	1.82	i_2	17.5	ω_2	1884					
	t_1	1.08	i_1	35.02	ω_1	1785				1.48	2.33
	t_2	1.57	i_2	18.27	ω_2	1876					

Table 12
Parameter estimation for 50V

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2											
MEASURED VARIABLES							ESTIMATED PARAMETERS				
	t (ms)		I (A)		ω (rad/s)		K (Nm/A)	R (Ω)	B (Nms/rad)	L (mH)	J (Kgm^2)
T_L=0 B=1e^{-4}Nms/rad step interval=1e^{-3}s	t_1	2.10	i_1	8.04	ω_1	944	0.05	0.48	1e^{-4}	0.924	2.62
	t_2	2.80	i_2	5.12	ω_2	996					
	t_1	1.57	i_1	9.16	ω_1	938				0.965	1.52
	t_2	2.10	i_2	7.36	ω_2	945					
	t_1	1.32	i_1	15.22	ω_1	931				1.25	2.221
	t_2	1.82	i_2	8.53	ω_2	942					
	t_1	1.08	i_1	17.85	ω_1	892				0.98	1.78
	t_2	1.57	i_2	9.14	ω_2	938					

Table 13
Parameter estimation for 50V

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2											
MEASURED VARIABLES							ESTIMATED PARAMETERS				
	t (ms)		I (A)		ω (rad/s)		K (Nm/A)	R (Ω)	B (Nms/rad)	L (mH)	J (Kgm^2)
T_L=0 B=1e^{-4}Nms/rad step interval=1e^{-3}s	t_1	2.10	i_1	3.12	ω_1	472	0.05	0.5	1e^{-4}	0.52	1.44
	t_2	2.80	i_2	2.01	ω_2	498					
	t_1	1.57	i_1	4.27	ω_1	469				0.86	1.56
	t_2	2.10	i_2	3.12	ω_2	472					
	t_1	1.32	i_1	6.28	ω_1	435				1.25	2.22
	t_2	1.82	i_2	4.36	ω_2	471					
	t_1	1.08	i_1	6.02	ω_1	431				1.45	2.001
	t_2	1.57	i_2	4.27	ω_2	470					

Table 14
Error calculation for 100V

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2												
condition	t (ms)		K (Nm/A)		R (Ω)		B (Nms/rad)		L (mH)		J (Kgm^2)	
	t_1	t_2	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR
V=100V	1.03	2.41	0.05	0	0.5	0	1e^{-4}	0	0.88	16.5	2.14	0.27
	1.88	2.81							0.90	15.3	2.3	0.89
	2.11	3.75							0.18	11.7	1.77	2.6
	3.75	5.24							0.11	11.7	1.53	2.78

Table 15
Error calculation for 50V

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2												
condition	t (ms)		K (Nm/A)		R (Ω)		B (Nms/rad)		L (mH)		J (Kgm^2)	
	t_1	t_2	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR
V=50V	2.10	2.80	0.05	0	0.5	0	1e^{-4}	0	1.6	20.6	2.507e^{-4}	0.27
	1.57	2.10							0.9	25.3	3.593e^{-4}	30.4
	1.32	1.82							1.7	11.7	3.593e^{-4}	2.6
	1.08	1.57							1.2	21.7	2.076e^{-4}	20.4

Table 16
Error calculation for 25V

ORIGINAL VALUES: K=0.05Nm/A, R=0.5Ω, B=1e^{-4}Nms/rad, L=1.5mH, J=2.5e^{-4}Kgm^2												
condition	t (ms)		K (Nm/A)		R (Ω)		B (Nms/rad)		L (mH)		J (Kg$\boldsymbol{m^2}$)	
	$\boldsymbol{t_1}$	$\boldsymbol{t_2}$	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR	EST VALUE	ERR
V=25V	2.10	2.80	0.05	0	0.5	0	$1e^{-4}$	0	1.8	16.6	$2.507e^{-4}$	0.27
	1.57	2.10							1.3	15.3	$3.593e^{-4}$	30.4
	1.32	1.82							1.5	21.7	$3.593e^{-4}$	2.6
	1.08	1.57							1.7	11.7	$2.076e^{-4}$	20.4

5 PARAMETER ESTIMATION USING REGRESSION METHOD

From the Dynamic Equation of Dc Motor
From the electrical equation

$$L\,\Delta i + i\,\Delta t\,R + \omega\,\Delta t\,K = V\,\Delta t \quad (16)$$

$$\begin{bmatrix} \Delta i_1 & \Delta t_1 i_1 & \Delta t_1 \omega_1 \\ \Delta i_2 & \Delta t_2 i_2 & \Delta t_2 \omega_2 \\ \Delta i_3 & \Delta t_3 i_3 & \Delta t_3 \omega_3 \end{bmatrix} \begin{bmatrix} L \\ R \\ k \end{bmatrix} = \begin{bmatrix} V_1 \Delta t_1 \\ V_2 \Delta t_2 \\ V_3 \Delta t_3 \end{bmatrix} \quad (17)$$

From the mechanical equation

$$J\Delta\omega + \omega\Delta t\,B + \Delta t\,T_L = V\,\Delta t \quad (18)$$

$$\begin{bmatrix} \Delta\omega_1 & \Delta t_1 \omega_1 & \Delta t_1 \\ \Delta\omega_2 & \Delta t_2 \omega_2 & \Delta t_2 \\ \Delta\omega_3 & \Delta t_3 \omega_3 & \Delta t_3 \end{bmatrix} \begin{bmatrix} J \\ B \\ T_L \end{bmatrix} = \begin{bmatrix} K\, i_1 \Delta t_1 \\ K\, i_2 \Delta t_2 \\ K i_3 \Delta t_3 \end{bmatrix} \quad (19)$$

5.1 ELECTRICAL PARAMETERS IDENTIFICATION

At different time interval, current and speed values were taken.This measured values are applied in equation (18) and the electrical parameters were sampling interval $7e^{-3}$s.

Table 17

Parameter estimation for 0.015s interval

MEASURED VARIABLES		ESTIMATED VALUES J (Kgm^2)	B (Nms/rad)	T_L (Nm)
t_1	0.015	1.3	0.479	0.050
t_2	0.03			
t_3	0.045			
Δt_1	-0.015			
Δt_2	-0.015			
Δt_3	-0.015			
i_1	1.356			
i_2	1.246			
i_3	0.995			
Δi_1	-1.356			
Δi_2	0.110			
Δi_3	0.251			
ω_1	4.075			
ω_2	7.722			
ω_3	10.466			

Table 20

Error calculation for electrical parameter

L(H)		R(Ω)		K(Nm/A)	
EST_ VALUE	ERR (%)	EST_ VALUE	ERR (%)	EST_ VALUE	ERR (%)
$1.3e^{-3}$	15.38	0.476	5.04	0.050	0
$1.8e^{-3}$	16.66	0.511	2.15	0.049	2.04
$2.1e^{-3}$	28.57	0.504	0.79	0.050	0

Table 18

Parameter estimation for 0.01s interval

MEASURED VARIABLES		ESTIMATED VALUES J (Kgm^2)	B (Nms/rad)	T_L (Nm)
t_1	0.02	1.8	0.511	0.0498
t_2	0.03			
t_3	0.04			
Δt_1	-0.01			
Δt_2	0.01			
Δt_3	0.01			
i_1	1.366			
i_2	1.244			
i_3	1.076			
Δi_1	-0.184			
Δi_2	0.12			
Δi_3	0.17			
ω_1	5.395			
ω_2	7.722			
ω_3	9.647			

Table 19

Parameter estimation for different time interval

MEASURED VARIABLES		ESTIMATED VALUES J (Kgm^2)	B (Nms/rad)	T_L (Nm)
t_1	0.02	2.1	0.504	0.050
t_2	0.05			
t_3	0.1			
Δt_1	0.01			
Δt_2	0.03			
Δt_3	0.05			
i_1	1.366			
i_2	0.919			
i_3	0.467			
Δi_1	0.1854			
Δi_2	0.447			
Δi_3	0.452			
ω_1	5.395			
ω_2	11.215			
ω_3	15.481			

5.3 ERROR CALCULATION FOR ELECTRICAL PARAMETERS

5.4 MECHANICAL PARAMETERS IDENTIFICATION

From fig (2) and fig (3) current and speed values were measured by applying this measured values in equation (19), mechanical parameters at sampling interval are obtained at $7e^{-3}$s this it is found that the regression method is not suitable to identify the mechanical parameter.

Table 21

Estimation of J, B, T_L at ω_1=14rad/s, ω_2=10rad/s, ω_3=2rad/s

MEASURED VARIABLES		ESTIMATED VALUES		
		J (Kgm^2)	B (Nms/rad)	T_L (Nm)
t_1	0.075	0.001	-0.0036	0.0806
t_2	0.042			
t_3	0.0089			
Δt_1	0.1048			
Δt_2	0.034			
Δt_3	0.033			
i_1	0.625			
i_2	1.053			
i_3	1.776			
ω_1	14.0			
ω_2	10.0			
ω_3	2.0			
$\Delta\omega_1$	2.0			
$\Delta\omega_2$	4.0			
$\Delta\omega_3$	8.0			

Table 22

Estimation of J, B, T_L at ω_1=2rad/s, ω_2=10rad/s, ω_3=14rad/s

MEASURED VARIABLES		ESTIMATED VALUES		
		J(Kgm^2)	B(Nms/rad)	T_L(Nm)
t_1	0.0089	0.001	-0.0031	0.0736
t_2	0.042			
t_3	0.075			
Δt_1	0.031			
Δt_2	0.034			
Δt_3	0.1048			
i_1	1.776			
i_2	1.053			
i_3	0.625			
ω_1	2.0			
ω_2	10.0			
ω_3	14.0			
$\Delta\omega_1$	8.0			
$\Delta\omega_2$	4.0			
$\Delta\omega_3$	2.0			

6 CONCLUSION

The table 23 gives the advantages and disadvantages of all the methods. The table reveals that each method has its own advantages and disadvantages. The future work is to implement real time parameter identification.

Table 23

Advantages and disadvantages of each methods

METHOD	ADVANTAGES	DISADVANTAGES
Effect of various load at sampling interval	Sampling interval $5e^{-3}$s gives the minimum error (L&J) The sampling interval $1e^{-3}$s gives the minimum error (R, B, and K).	Error increases as the sampling interval increases.
Effect of excitation voltage on parameter identification	Sampling interval $1e^{-3}$s gives the minimum error	It requires various voltages.
Parameter identification using regression method	This method is suitable to identify only the electrical parameters. The time interval of 0.015s gives the minimum value of error.	This method is not suitable to identify the mechanical parameter.

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