Practical Motor Starting

Richard W. Fruge, P.E. (Inactive)

Course Content

Motor acceleration time at various terminal voltage levels must often be determined to evaluate protective device performance or for power system studies. This module presents a well-documented methodology that is often used by engineers and requires only published motor and load data. The methodology presented here calculates a current exponent ratio and a torque exponent ratio that more accurately describes motor performance at reduced voltage levels. In order to enhance the utility of this methodology, a "real world" example that includes a belt driven fan load is used. A template that can be readily used in other motor acceleration time calculations will be developed.

Equations describing motor performance will be presented to demonstrate the relationship between the various motor parameters used to calculate motor acceleration time. Equations describing fan performance will be presented to demonstrate the relationship between the various fan parameters and the impact of load performance on the motor driving that load. An exercise using the motor and load equations will then be presented to demonstrate the motor starting time calculation methodology.

Evaluation of the acceleration time at a different motor terminal voltage requires re-calculation of the motor torque and accelerating torque. "Automating" the calculation can minimize the impact of this requirement. A toolbox automating the motor starting time calculation is presented in this module to demonstrate the time saving and error reduction potential. A general discussion of a calculation "automation" process is also presented to detail the resource requirements for implementing such a process. A working copy of the toolbox is available at no additional cost to the engineer using this module.

I. MOTOR EQUATIONS

The general equation for motor acceleration time, t, is:

$$t = \frac{wk^2 \times N}{308T_n} \qquad \textbf{(Eq. 1)}$$

where

wk^2 = Inertia of the motor and load (lb-ft^2)

N = Motor speed (RPM)

T_n = Accelerating torque (ft-lb)

Accelerating torque is the torque available to accelerate the load. The load speed-torque curve and the motor speed-torque curve are divided into increments of at least 10% of motor speed (ΔN) and the torque at the center of each increment ($T_{n\,avg}$ for each ΔN) can be used to calculate the acceleration time.

$$t_{tot} = \sum \frac{wk^2 \times \Delta N}{308T_{n\,avg}} \qquad \textbf{(Eq. 2)}$$

Since our example uses a belt driven fan load, the equivalent inertia of the load must be "referred" to the prime mover. The inertia of driven equipment (driven by pulleys) is referred to the motor shaft as follows:

$$wk^2_{eff} = \frac{RPM^2_{load}}{RPM^2_{motor}} \times wk^2 \qquad \textbf{(Eq. 3)}$$

Similarly, the torque of equipment driven by pulleys can be referred to the motor shaft as follows:

$$T_{eff} = \frac{RPM_{load}}{RPM_{motor}} \times T_{load} \qquad \textbf{(Eq. 4)}$$

Motor nameplates generally contain the following data:

1. Voltage
2. Horsepower rating
3. Rated speed
4. FLA - Full Load Amps
5. LRA – Locked Rotor Amps
6. PF – Power Factor

This data and motor performance curves are usually provided in documentation supplied with the motor. Data associated with motor performance at a reduced terminal voltage is sometimes provided, if required by the motor specification.

The relationship between horsepower and torque is given by the equation:

$$T = \frac{hp \times 5250}{RPM} \quad lb-ft \qquad \textbf{(Eq. 5)}$$

Motor manufacturers indicate the following conditions are likely to occur with variations in voltage:

1. An increase or decrease in voltage may result in increased heating at rated horsepower load. Extended operation at other than nameplate voltage may accelerate insulation deterioration and shorten motor insulation life.

2. Increases in voltage will usually result in a decrease in power factor, while a decrease in voltage will result in an increase in power factor.

3. Locked-rotor and breakdown torque will be proportional to the square of the voltage. Therefore, a decrease in voltage will result in a decrease in available torque. (Reference Equations 6 & 7 below).

4. An increase in voltage will result in a reduction of slip. A voltage reduction would increase slip.

IEEE Standard 112 (Reference 1) allows motor performance to be determined based on tests made at reduced voltage. The standard also states "..it should be recognized that, because of saturation of the leakage flux paths, the current may increase by a ratio greater than the first power of the voltage; and the torque may increase by a ratio greater than the square of the voltage. The relationship varies with design; however, as a first approximation, the current is calculated as varying directly with voltage, and torque with the square of the voltage."

Motor vendors using this method generally use a more exact method, which is to determine the rate of change of current and torque with voltage. The reduced voltage test points are plotted on log-log paper and corrected to rated voltage using a least squares curve fit for maximum accuracy. This results in the determination of a Torque Exponent Ratio and a Current Exponent Ratio for the motor.

The Torque Exponent Ratio is calculated using the corrected full voltage locked rotor torque and reduced voltage locked rotor torque as follows:

$$K1 = \frac{Log(T_{lrfv}) - Log(T_{lrrv})}{Log\left(\frac{V_{fv}}{V_{rv}}\right)} \qquad \textbf{(Eq. 6)}$$

Motor performance curves can be used to calculate motor parameters at reduced terminal voltage values as follows:

$$T_{V2} = \left(\frac{V2}{V1}\right)^{K1} \times T_{V1} \qquad \textbf{(Eq. 7)}$$

where:

T_{V2} = Torque at voltage 2

T_{V1} = Torque at voltage 1

T_{V1} and V1 are usually extrapolated from motor performance data (i.e. read from the performance curve).

The Current Exponent Ratio is calculated using the full voltage locked rotor current and reduced voltage locked rotor current as follows:

$$K2 = \frac{Log(I_{lrfv}) - Log(I_{lrrv})}{Log\left(\frac{V_{fv}}{V_{rv}}\right)} \qquad \textbf{(Eq. 8)}$$

Motor performance curves can be used to calculate motor parameters at reduced terminal voltage values as follows:

$$I_{V2} = \left(\frac{V2}{V1}\right)^{K2} \times I_{V1} \qquad \textbf{(Eq. 9)}$$

where:

I_{V2} = Current at voltage 2

I_{V1} = Current at voltage 1

I_{V1} and V1 are usually extrapolated from motor performance data (i.e. read from the performance curve or from test data). Equations 8 & 9 are used to calculate reduced voltage motor currents at locked rotor, pull up, and break down points. This is a direct result of the fact that a motor exhibits characteristics of a "constant impedance" device while starting and characteristics of a "constant KVA" device while running. Using the equation for calculating the KVA load of a running motor as follows, one can readily see the "constant KVA" characteristics:

$$KVA = \frac{bhp \times 0.746 \frac{KW}{hp}}{PF \times Eff}$$

An estimated Torque Exponent Ratio of 2.2 and Current Exponent Ratio of 1.1 can be used when test data is not available (Reference 2) for calculating these values.

II. FAN EQUATIONS

Equations related to fan performance are presented here to provide a means of evaluating effects on motor loading. The equations provided can also be used to evaluate the impact of motor terminal voltage variations on fan performance.

Equations 10, 11, and 12 below are frequently called the “Fan Laws”. Fan performance parameters include Cubic Feet per Minute (CFM), Static Pressure (SP), and Brake Horsepower (BHP). Subscript 1 refers to existing conditions and subscript 2 refers to new conditions.

$$CFM_2 = \left(\frac{RPM_2}{RPM_1}\right) \times CFM_1 \qquad \textbf{(Eq. 10)}$$

$$SP_2 = \left(\frac{RPM_2}{RPM_1}\right)^2 \times SP_1 \qquad \textbf{(Eq. 11)}$$

$$BHP_2 = \left(\frac{RPM_2}{RPM_1}\right)^3 \times BHP_1 \qquad \textbf{(Eq. 12)}$$

Equation 5 and Equation 12 can be used to derive a torque-speed relationship for the fan. This is useful when a torque-speed curve for a motor is to include the fan curve. The fan torque-speed relationship shown in Figure 1 is given by:

$$T_2 = \left(\frac{RPM_2}{RPM_1}\right)^2 \times T_1 \qquad \textbf{(Eq. 13)}$$

Equations 10 through 13 demonstrate the effect that a change in motor speed or gear/pulley ratio would have on fan performance and motor requirements. For example, any change that increases the fan RPM would result in the following:

- increased air flow (equation 10). This change would be proportional to the speed change.
- increased static pressure (equation 11). This change would be proportional to the square of the speed change.
- increased motor hp to drive the load (equation 12).
- increased motor torque requirement (equation 13). This change would be proportional to the square of the speed change of the fan, then translated to the motor shaft in accordance with equation 4.

III. Exercise for Motor Acceleration Time Calculation

A motor starting time calculation at 80% rated terminal voltage will be used to demonstrate the concepts discussed above.

<u>Load Data</u>
Fan performance at 100% design speed are specified as follows:

BHP = 130 hp
wk^2 = 450 lb-ft^2
RPM = 960

Using the Torque-hp relationship given in Eq. 5:

$$T = \frac{hp \times 5250}{RPM} = 710.94 \, lb - ft \, .$$

This value can then be used to generate a fan torque-speed curve using the Torque-speed relationship given in Eq. 13 as follows:

$$T_2 = T_1 \times \left(\frac{RPM_2}{RPM_1}\right)^2$$

The resulting fan torque-speed curve is shown on Figure 1.

The fan is driven with a belt on a 16” sheave at the fan and a 9” sheave at the motor. This results in fan speed that is (9/16) x motor speed (i.e.

56.25%). The load torque referred to the motor shaft is calculated using Eq. 4 as follows:

$$T_{eff} = \frac{RPM_{load}}{RPM_{motor}} \times T_{load}$$

$$T_{eff} = .5625 \times T_{load}$$

The fan inertia referred to the motor shaft is calculated using Eq. 3 as follows:

$$wk^2_{eff} = \frac{RPM^2_{load}}{RPM^2_{motor}} \times wk^2$$

$$wk^2_{eff} = .5625^2 \times 450 = 142.383\ lb-ft^2$$

Motor Data

The following motor parameters are provided:

Locked Rotor Current = 920 A
Locked Rotor Torque = 700 lb-ft
wk^2 = 80 lb-ft^2
Torque Exponent Ratio = 2.25
Current Exponent Ratio = 1.15
Voltage Rating = 460 V
Speed = 1785 RPM

The motor speed-torque curve is provided in Figure 2. This curve also contains the Figure 1 fan speed-torque characteristics referred to the motor shaft using Eq. 4. In order to demonstrate the starting time calculation, Table 1 lists the motor speed-torque values, Table 2 lists the fan (load) speed-torque values, and Table 3 provides the accelerating torque ($T_{n\ avg}$) values.

Table 1 (Motor)

% Speed	ΔN rpm	T_{avg} lb-ft
0 - 10	180	685
10 - 20	180	660
20 - 30	180	640
30 – 40	180	638
40 – 50	180	638
50 – 60	180	642
60 – 70	180	650
70 – 80	180	685
80 – 90	180	775
90 – 94	72	880
94 – 96	36	1080
96 – 98	36	1125
98 – 99.2	21.6	800

Table 2 (Fan T_{eff})

% Speed	ΔN rpm	T_{avg} lb-ft
0 - 10	180	1.11
10 - 20	180	10.01
20 - 30	180	27.8
30 – 40	180	54.49
40 – 50	180	90.08
50 – 60	180	134.56
60 – 70	180	187.94
70 – 80	180	250.22
80 – 90	180	321.4
90 – 94	72	376.51
94 – 96	36	401.47
96 – 98	36	418.55
98 – 99.2	21.6	432.47

Table 3 (Accelerating Torque)

% Speed	ΔN rpm	$T_{n\ avg}$ lb-ft
0 - 10	180	683.89
10 - 20	180	649.99
20 - 30	180	612.20
30 – 40	180	583.51
40 – 50	180	547.92
50 – 60	180	507.44
60 – 70	180	462.06
70 – 80	180	434.78
80 – 90	180	453.60
90 – 94	72	503.49
94 – 96	36	678.53
96 – 98	36	706.45
98 – 99.2	21.6	367.53

Using Eq. 2 for each of the intervals in the tables to calculate the time interval:

$$t_1 = \frac{222.383 \times 180}{308 \times 683.89} = 0.19004\ sec$$

$$t_2 = \frac{222.383 \times 180}{308 \times 649.99} = 0.19995\ sec$$

$$t_3 = \frac{222.383 \times 180}{308 \times 612.20} = 0.21229\ sec$$

$$t_4 = \frac{222.383 \times 180}{308 \times 583.51} = 0.22273\ sec$$

$$t_5 = \frac{222.383 \times 180}{308 \times 547.92} = 0.23720\ sec$$

$$t_6 = \frac{222.383 \times 180}{308 \times 507.44} = 0.25612 \text{ sec}$$

$$t_7 = \frac{222.383 \times 180}{308 \times 462.06} = 0.28127 \text{ sec}$$

$$t_8 = \frac{222.383 \times 180}{308 \times 434.78} = 0.29892 \text{ sec}$$

$$t_9 = \frac{222.383 \times 180}{308 \times 453.60} = 0.28652 \text{ sec}$$

$$t_{10} = \frac{222.383 \times 72}{308 \times 503.49} = 0.10325 \text{ sec}$$

$$t_{11} = \frac{222.383 \times 36}{308 \times 678.53} = 0.03831 \text{ sec}$$

$$t_{12} = \frac{222.383 \times 36}{308 \times 706.45} = 0.03679 \text{ sec}$$

$$t_{13} = \frac{222.383 \times 21.6}{308 \times 367.53} = 0.04243 \text{ sec}$$

$$t_{start} = \sum_{1}^{13} t = 2.40581 \text{ sec}$$

In order to demonstrate the starting time calculation at 80% motor terminal voltage, Table 4 lists the motor speed-torque values. The torque values are calculated using the Table 1 torque values and Eq. 7. Table 2 is used for the fan (load) speed-torque values, since the lower motor terminal voltage does not affect the fan characteristics. Table 5 provides the new (Table 4 minus Table 2) accelerating torque ($T_{n\,avg}$) values.

Table 4 (Motor 80% terminal voltage)

% Speed	ΔN rpm	T_{avg} lb-ft
0 - 10	180	414.61
10 - 20	180	399.48
20 - 30	180	387.38
30 – 40	180	386.17
40 – 50	180	386.17
50 – 60	180	388.59
60 – 70	180	393.43
70 – 80	180	414.61
80 – 90	180	469.09
90 – 94	72	532.64
94 – 96	36	653.70
96 – 98	36	680.93
98 – 99.2	21.6	484.22

Table 5 (Accelerating Torque)

% Speed	ΔN rpm	$T_{n\,avg}$ lb-ft
0 - 10	180	413.50
10 - 20	180	389.47
20 - 30	180	359.58
30 – 40	180	331.68
40 – 50	180	296.09
50 – 60	180	254.03
60 – 70	180	205.49
70 – 80	180	164.39
80 – 90	180	147.69
90 – 94	72	156.13
94 – 96	36	252.23
96 – 98	36	262.38
98 – 99.2	21.6	51.75

$$t_1 = \frac{222.383 \times 180}{308 \times 413.50} = 0.31430 \text{ sec}$$

$$t_2 = \frac{222.383 \times 180}{308 \times 389.47} = 0.33369 \text{ sec}$$

$$t_3 = \frac{222.383 \times 180}{308 \times 359.58} = 0.36144 \text{ sec}$$

$$t_4 = \frac{222.383 \times 180}{308 \times 331.68} = 0.39184 \text{ sec}$$

$$t_5 = \frac{222.383 \times 180}{308 \times 296.09} = 0.43894 \text{ sec}$$

$$t_6 = \frac{222.383 \times 180}{308 \times 254.03} = 0.51162 \text{ sec}$$

$$t_7 = \frac{222.383 \times 180}{308 \times 205.49} = 0.63246 \text{ sec}$$

$$t_8 = \frac{222.383 \times 180}{308 \times 164.39} = 0.79057 \text{ sec}$$

$$t_9 = \frac{222.383 \times 180}{308 \times 147.69} = 0.87999 \text{ sec}$$

$$t_{10} = \frac{222.383 \times 72}{308 \times 156.13} = 0.33296 \text{ sec}$$

$$t_{11} = \frac{222.383 \times 36}{308 \times 252.23} = 0.10305 \text{ sec}$$

$$t_{12} = \frac{222.383 \times 36}{308 \times 262.38} = 0.09906 \text{ sec}$$

$$t_{13} = \frac{222.383 \times 21.6}{308 \times 51.75} = 0.30137 \text{ sec}$$

$$t_{start} = \sum_{1}^{13} t = 5.49130 \text{ sec}$$

The starting time at 80% motor terminal voltage has more than doubled the time calculated at rated motor terminal voltage, as expected. It is interesting to note here that the most widely used methodology for calculating motor starting time "assumes" that the torque varies with the square of the voltage ratio. Using that methodology would have resulted in a starting time of 4.85414 seconds in this example exercise. It is obvious that the difference resulting from that assumption would affect system voltage studies using static motor starting models.

If the torque exponent ratio was not known to be 2.25 as specified in this exercise, and using the assumption that K = 2.2 (Reference 2) yields a starting time of 5.34772 seconds. The difference resulting from this assumption would have a much less severe impact on system studies.

IV. AUTOMATION

The discussion presented in the previous sections of this module provides an excellent case for automating a calculation process. The same equations are solved for multiple data points. Therefore, development of a program to store the data and solve the equations for all the data would appear to be a reasonable endeavor. Automation of this process not only simplifies the calculation, but also reduces the possibility of errors.

Figures 3 & 4 show the output of a motor start time program developed using Microsoft Access 97. The output represents the results of the example exercise at 100% and 80% motor terminal voltage. The program implements the motor starting time calculation described in equations 1 & 2. Use of a database eliminates the need for specially formatted data files and provides an intuitive user interface (input forms). Additionally, use of a database allows for storage of motor and load performance data for reuse in many motor case studies.

Forms are designed to perform and store the results of the torque exponent ratio and current exponent ratio calculations described in equations 6 & 8. All the attributes and properties of a relational database are used to minimize required input. The capability to calculate reduced voltage locked rotor torque for an assumed torque exponent ratio is also included.

The program uses the stored performance data to generate a report that contains the starting time calculation results in a tabular format. The computations are made inside the report, eliminating the requirement to store the results in the database. Motor starting time can be evaluated at a different voltage level by entering the new voltage, selecting "UPDATE", then printing the results.

Development of programs of this type eliminates the computational aspects of motor starting calculations and would require an investment of 40 to 50 man hours. The possibilities for automation are endless, and customization to meet specific requirements is easily achieved by engineers with minimal programming skills.

Students using this module for PDH credit may request a free copy of the program described above. This will enable them to explore the benefits that could be realized by automating repetitive tasks, as well as provide them with a sense of what is involved in the application of an automated approach to calculation systems. Email the author to request your free copy of the tool at

rwfruge@yahoo.com.

The flexibility of this automated calculation tool will now be demonstrated by analyzing a “what if” example using the program described above.

What if the motor vendor rating for the motor was changed to include a torque exponent ratio (K1) of 2.15 and the minimum motor terminal voltage was 90%. Compare the results with Figure 4.

You would copy the Figure 3 performance data and paste to a new record (Figure 5). Select the Torque Exponent Ratio tab, enter the full voltage torque, enter 90 % for the voltage ratio, enter 2.15 for the Torque Exponent Ratio, and then press CALCULATE T2. Return to the Motor Data tab and observe that TEST VOLTS is 90% and the reduced voltage locked rotor torque value is 558.110. Use HEADERS to prepare the desired report header, then press PRINT RESULTS. When compared to the results in Figure 4, observe that the reduce voltage motor torque values and the net (accelerating) torque values have increased and the resulting starting time has been reduced to 3.3184 seconds. As expected, the new starting time is greater than the full voltage starting time and less than the 80% voltage starting time.

V. SUMMARY

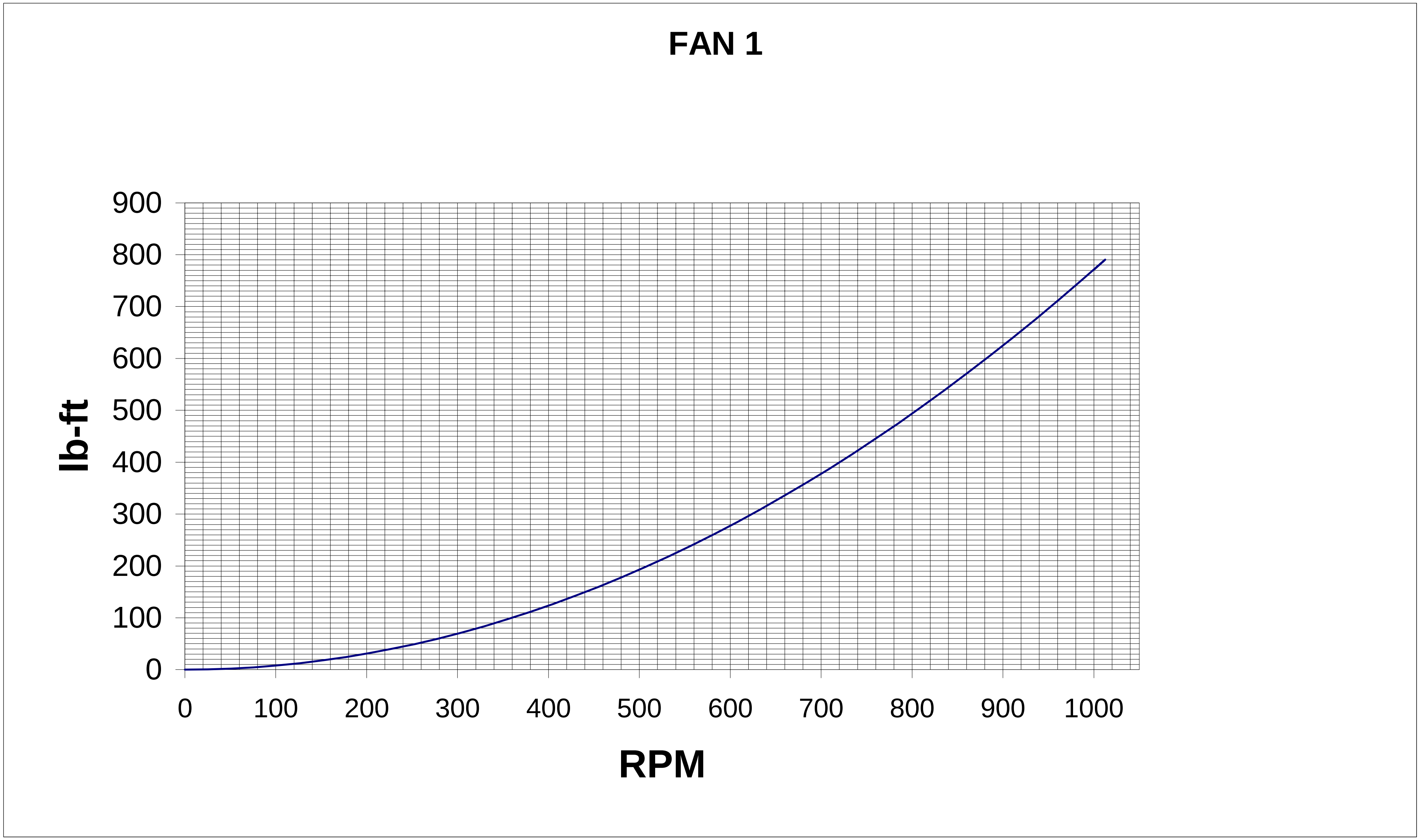
Methods are described to analyze motor starting time with reduced motor terminal voltage. The methods described include the generally accepted assumption that the torque varies with the square of the voltage ratio, as well as use of reduced voltage test data to more precisely calculate the impact of voltage on the motor torque. Equations for "translating" belt driven load data to the motor shaft are presented. The Fan Laws are also provided to demonstrate the impact that motor RPM changes would have on fan performance. The practice exercise demonstrates the repetitive calculations required to evaluate the motor accelerating time and the impact of reduced motor terminal voltage on those calculations. Examples included full voltage and 80% voltage cases.

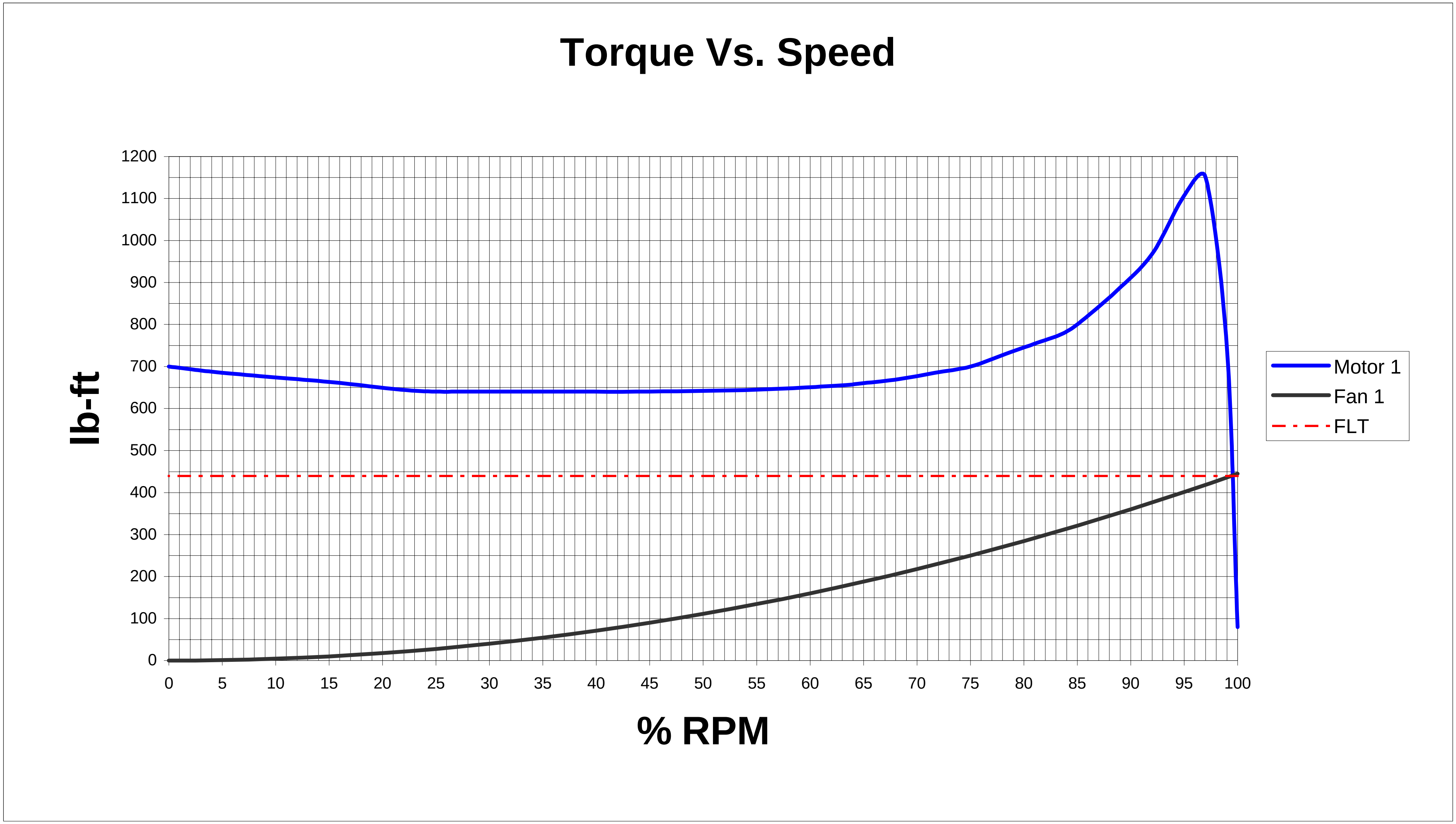
An automated calculation tool is presented and an analysis of motor starting time with different terminal voltage and motor torque characteristics demonstrates the benefits of "automating" calculations. The program is provided to users of this module to demonstrate automation possibilities.

References

1. IEEE Standard 112, 1991

2. EPRI Power Plant Electrical Reference Series, Volume 6, Motors, Dated 1987.


FAN 1
lb-ft
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
RPM


Torque Vs. Speed
lb-ft
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
% RPM
Motor 1
Fan 1
FLT

Practical Motor Starting
Motor Starting Time Example

Figure 3
Page 1 of 1

Motor 1

Voltage	460	V	**Terminal Voltage**	100 **%**
Speed	1800	RPM	**Torque Exponent**	2.2500
Inertia	222.383	lb-ft^2		

Speed Increment (%)	**Speed Increment (RPM)**	**Motor Torque (lb-ft) FV**	**Motor Torque (lb-ft) RV**	**Load Torque (lb-ft)**	**Net Torque (lb-ft)**	**Time (Sec)**
0.00 - 10.00	180.00	685.00	685.00	1.11	683.89	0.19004
10.00 - 20.00	180.00	660.00	660.00	10.01	649.99	0.19995
20.00 - 30.00	180.00	640.00	640.00	27.80	612.20	0.21229
30.00 - 40.00	180.00	638.00	638.00	54.49	583.51	0.22273
40.00 - 50.00	180.00	638.00	638.00	90.08	547.92	0.23720
50.00 - 60.00	180.00	642.00	642.00	134.56	507.44	0.25612
60.00 - 70.00	180.00	650.00	650.00	187.94	462.06	0.28127
70.00 - 80.00	180.00	685.00	685.00	250.22	434.78	0.29892
80.00 - 90.00	180.00	775.00	775.00	321.40	453.60	0.28652
90.00 - 94.00	72.00	880.00	880.00	376.51	503.49	0.10325
94.00 - 96.00	36.00	1080.00	1080.00	401.47	678.53	0.03831
96.00 - 98.00	36.00	1125.00	1125.00	418.55	706.45	0.03679
98.00 - 99.20	21.60	800.00	800.00	432.47	367.53	0.04243
				Total Starting Time		2.40581

NOTES:
Fan wk^2 = 450 lb-ft^2
Motor wk^2 = 80 lb-ft^2
Total wk^2 = 222.383 lb-ft^2

Practical Motor Starting **Figure 4**
Motor Starting Time Example **Page 1 of 1**

Motor 1

Voltage	460	V	**Terminal Voltage**	80 ***%***
Speed	1800	RPM	**Torque Exponent**	2.2500
Inertia	222.383	lb-ft^2		

Speed Increment (%)	Speed Increment (RPM)	Motor Torque (lb-ft) FV	RV	Load Torque (lb-ft)	Net Torque (lb-ft)	Time (Sec)
0.00 - 10.00	180.00	685.00	414.61	1.11	413.50	0.31430
10.00 - 20.00	180.00	660.00	399.48	10.01	389.47	0.33369
20.00 - 30.00	180.00	640.00	387.38	27.80	359.58	0.36144
30.00 - 40.00	180.00	638.00	386.17	54.49	331.68	0.39184
40.00 - 50.00	180.00	638.00	386.17	90.08	296.09	0.43894
50.00 - 60.00	180.00	642.00	388.59	134.56	254.03	0.51162
60.00 - 70.00	180.00	650.00	393.43	187.94	205.49	0.63246
70.00 - 80.00	180.00	685.00	414.61	250.22	164.39	0.79057
80.00 - 90.00	180.00	775.00	469.09	321.40	147.69	0.87999
90.00 - 94.00	72.00	880.00	532.64	376.51	156.13	0.33296
94.00 - 96.00	36.00	1080.00	653.70	401.47	252.23	0.10305
96.00 - 98.00	36.00	1125.00	680.93	418.55	262.38	0.09906
98.00 - 99.20	21.60	800.00	484.22	432.47	51.75	0.30137
				Total Starting Time		5.49130

NOTES:
Fan wk^2 = 450 lb-ft^2
Motor wk^2 = 80 lb-ft^2
Total wk^2 = 222.383 lb-ft^2

Practical Motor Starting
Motor Starting Time @ 90 %

Figure 5
Page 1 of 1

Motor 1

Voltage	460	V	**Terminal Voltage**	90 **%**
Speed	1800	RPM	**Torque Exponent**	2.1500
Inertia	222.383	lb-ft^2		

Speed Increment (%)	Speed Increment (RPM)	Motor Torque (lb-ft) FV	Motor Torque (lb-ft) RV	Load Torque (lb-ft)	Net Torque (lb-ft)	Time (Sec)
0.00 - 10.00	180.00	685.00	546.15	1.11	545.04	0.23845
10.00 - 20.00	180.00	660.00	526.22	10.01	516.21	0.25177
20.00 - 30.00	180.00	640.00	510.27	27.80	482.47	0.26937
30.00 - 40.00	180.00	638.00	508.68	54.49	454.19	0.28615
40.00 - 50.00	180.00	638.00	508.68	90.08	418.60	0.31048
50.00 - 60.00	180.00	642.00	511.87	134.56	377.31	0.34445
60.00 - 70.00	180.00	650.00	518.24	187.94	330.30	0.39347
70.00 - 80.00	180.00	685.00	546.15	250.22	295.93	0.43917
80.00 - 90.00	180.00	775.00	617.91	321.40	296.51	0.43832
90.00 - 94.00	72.00	880.00	701.62	376.51	325.11	0.15990
94.00 - 96.00	36.00	1080.00	861.08	401.47	459.61	0.05655
96.00 - 98.00	36.00	1125.00	896.96	418.55	478.41	0.05433
98.00 - 99.20	21.60	800.00	637.84	432.47	205.37	0.07594
				Total Starting Time		3.31834

NOTES:
Fan wk^2 = 450 lb-ft^2
Motor wk^2 = 80 lb-ft^2
Total wk^2 = 222.383 lb-ft^2