Industrial Maintenance

Motor Drives

Courseware Sample

87667-F0

Order no.: 87667-10
First Edition
Revision level: 08/2016

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Printed in Canada

ISBN 978-2-89640-466-7 (Printed version)
ISBN 978-2-89640-702-6 (CD-ROM)
Legal Deposit – Bibliothèque et Archives nationales du Québec, 2011
Legal Deposit – Library and Archives Canada, 2011

Safety and Common Symbols

The following safety and common symbols may be used in this manual and on the equipment:

Symbol	Description
DANGER	**DANGER** indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.
WARNING	**WARNING** indicates a hazard with a medium level of risk which, if not avoided, could result in death or serious injury.
CAUTION	**CAUTION** indicates a hazard with a low level of risk which, if not avoided, could result in minor or moderate injury.
CAUTION	**CAUTION** used without the *Caution, risk of danger* sign ⚠, indicates a hazard with a potentially hazardous situation which, if not avoided, may result in property damage.
	Caution, risk of electric shock
	Caution, hot surface
	Caution, risk of danger
	Caution, lifting hazard
	Caution, hand entanglement hazard
	Notice, non-ionizing radiation
	Direct current
	Alternating current
	Both direct and alternating current
	Three-phase alternating current
	Earth (ground) terminal

Safety and Common Symbols

Symbol	Description
	Protective conductor terminal
	Frame or chassis terminal
	Equipotentiality
	On (supply)
	Off (supply)
	Equipment protected throughout by double insulation or reinforced insulation
	In position of a bi-stable push control
	Out position of a bi-stable push control

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Preface

The Motor Drives Training System, model 8036-A, introduces the use of the AC and DC drives to control electric motors.

We hope that your learning experience will be the first step of a successful career.

We invite readers of this manual to send us their tips, feedback, and suggestions for improving the book.

Please send these to did@de.festo.com.

The authors and Festo Didactic look forward to your comments.

About This Manual

The exercises in this manual, Motor Drives, provide the knowledge necessary to perform motor controls with the help of motor drives

The present manual is divided into two units:

- Unit 1 introduces the AC Drive and its main functions;
- Unit 2 introduces the DC Drive and its main functions.

Each unit contains exercises which provide a systematic and realistic means of learning the subject matter. Each exercise is divided into the following sections:

- A clearly defined Exercise Objective;
- A Discussion of the theory involved in the exercise;
- A Procedure Summary which provides a bridge between the theoretical
- Discussion and the laboratory Procedure;
- A step-by-step laboratory Procedure in which the students observe and quantify important principles covered in the Discussion;
- A Conclusion to summarize the material presented in the exercise;
- Review Questions to verify that the material has been well assimilated.

A ten-question test at the end of each unit allows the student's knowledge of the unit material to be assessed.

Safety considerations

Safety symbols that may be used in this manual and on the equipment are listed in the Safety Symbols table at the beginning of the manual.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Make sure that you are wearing appropriate protective equipment when performing the tasks. You should never perform a task if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Prerequisite

This practical hands-on course is presented in a way that it is readily understandable by anyone who has knowledge of electromechanical systems. However it should be preferable to have completed the manual Basic Controls, part number 39163.

Before performing an exercise, you should read the pages of the AC-Drive or DC-Drive user manuals that deal with the covered topics. Ask your instructor for a copy, or download the file from the manufacturer's website.

About This Manual

Systems of units

Units are expressed using the International System of Units (SI) followed by units expressed in the U.S. customary system of units (between parentheses).

To the Instructor

You will find in this Instructor Guide all the elements included in the Student Manual together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to you is placed between markers and appears in red.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this manual should be considered as a guide. Students who correctly performed the exercises should expect to demonstrate the principles involved and make observations and measurements similar to those given as answers.

Considerations

- Before a student begins an exercise, ensure that the equipment is in good condition and does not represent any risk when used.
- This guide provides you with the answers to questions.
- Make sure that the students understand the objectives of the work to do.
- The default setting of some parameters depends on the Country parameter of the AC Drive. For this reason, the default setting values shown in the user guide may differ from the current default settings of the AC Drive.
- If the AC Drive OMRON is displaying error E12 even if nothing is connected to the Multi-function inputs, one of the Multi-function inputs is configured for a low-level signal (like the normally closed contact of the Emergency Button). To clear error E12, you must apply 24 V dc on this input. If you do not know which input is configured that way, apply 24 V dc (from terminal P24) to input S1 and try to clear the error. If it does not work, try again with input S2, S3, S4, and S5. Once the error is cleared, initialize the AC Drive by performing the Initialization procedure shown in the student manual.

Sample Exercise
Extracted from
the Student Manual
and the Instructor Guide

Ramp and Torque Boost

EXERCISE OBJECTIVE

In this exercise, you will:

- Understand the acceleration and deceleration time settings.
- Introduce the linear and S-shape acceleration and deceleration patterns.
- Introduce the Torque boost function.

DISCUSSION OUTLINE

The Discussion of this exercise covers the following points:

- Acceleration and deceleration times
- Acceleration and deceleration patterns
- Torque boost

DISCUSSION

Acceleration and deceleration times

The acceleration time defines the time duration in which the AC Drive reaches its maximum frequency after a start signal is issued. Short acceleration times are usually for light loads, and long acceleration times for heavy loads, or in applications requiring soft start such as a bottle conveyor. The Acceleration time function is also known as ramping. See Figure 1-10.

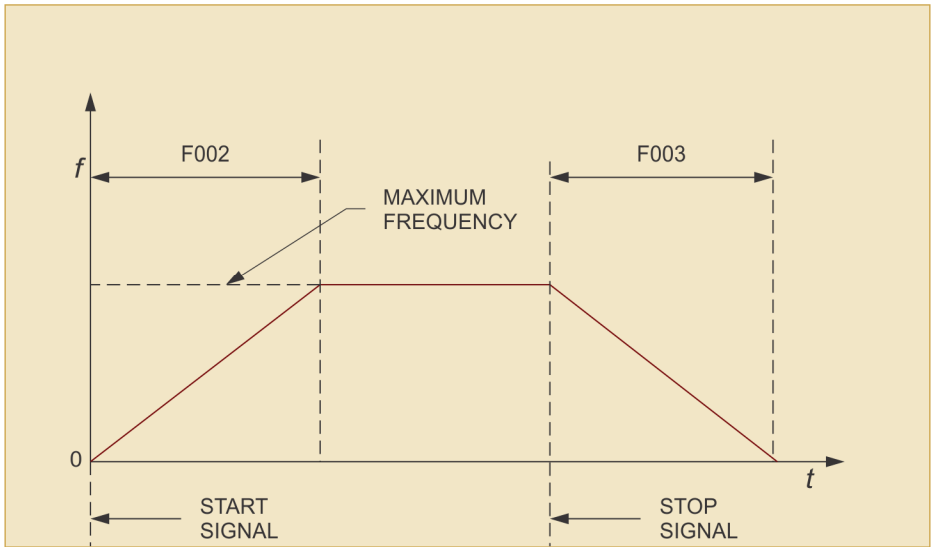


Figure 1-10. Acceleration/deceleration ramps.

Conversely, the deceleration time defines the time duration in which the AC Drive reduces the output frequency from the maximum frequency to 0 Hz after a stop signal. If the equipment connected to a motor has low friction and a lot of inertia,

it could coast for a long time. The Deceleration time function allows the load to be stopped more quickly.

The Acceleration time and Deceleration time functions are set using parameters F002 and F003. The characteristics of these parameters are shown in Table 1-8.

Table 1-8. Characteristics of parameters F002, F003, A097, and A098.

Parameter	Function	Value	DS
F002	*Acceleration time*	0.01 a 3000 s	10.00
F003	*Deceleration time*	0.01 a 3600 s	10.00
A097	*Acceleration pattern selection*	00: Líne 01: S-shape curve	00
A098	*Deceleration pattern selection*	00: Líne 01: S-shape curve	00

Acceleration and deceleration patterns

The acceleration and deceleration patterns can be linear or S shape. When a motor is started or stopped using the linear acceleration or deceleration patterns, its rate of change until it reaches full speed, or comes to a complete stop, is linear. See Figure 1-11.

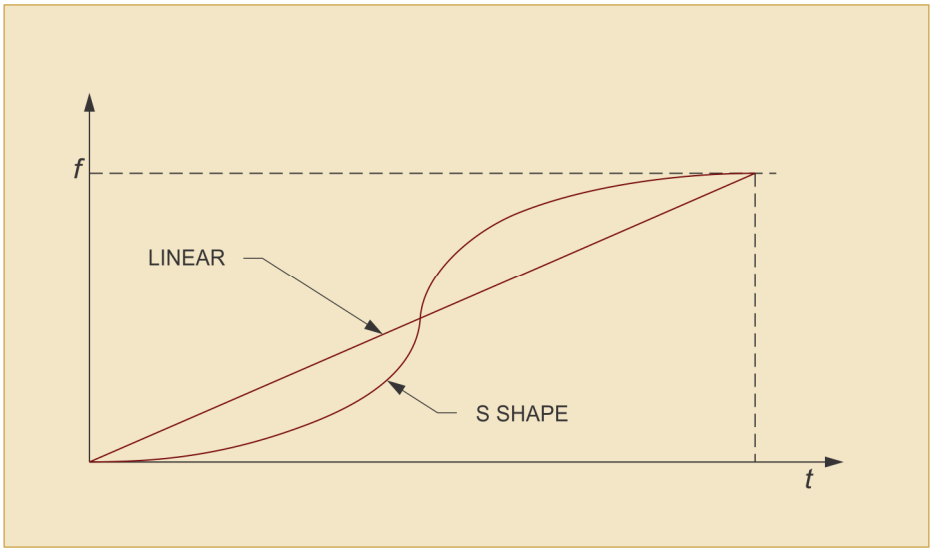


Figure 1-11. Linear and S-shape patterns during acceleration.

When the motor is started or stopped, using the S-shape acceleration or deceleration pattern, its rate of change gradually increases or decreases until it reaches full speed, or comes to a complete stop. The purpose of the S-shape pattern is to combine soft starts and soft stops with high speeds between them. The movement of an elevator is an example of the S-shape acceleration/deceleration pattern.

The Acceleration time and Deceleration time functions are set using parameters A097 and A098. The characteristics of these parameters are shown in Table 1-8.

Torque boost

If the mass inertia moment or static friction of the connected load is high, it may be necessary to increase (boost) the output voltage beyond the normal V/f characteristics at low output frequencies. This compensates for the voltage drop in the motor windings and can be up to half the motor's nominal voltage.

The torque boost (voltage increase) is defined as a percentage value. As Figure 1-12 shows, the Manual torque boost voltage function (parameter A042) is a percentage of the output voltage and the Manual torque boost frequency function (A043) is a percentage of the frequency.

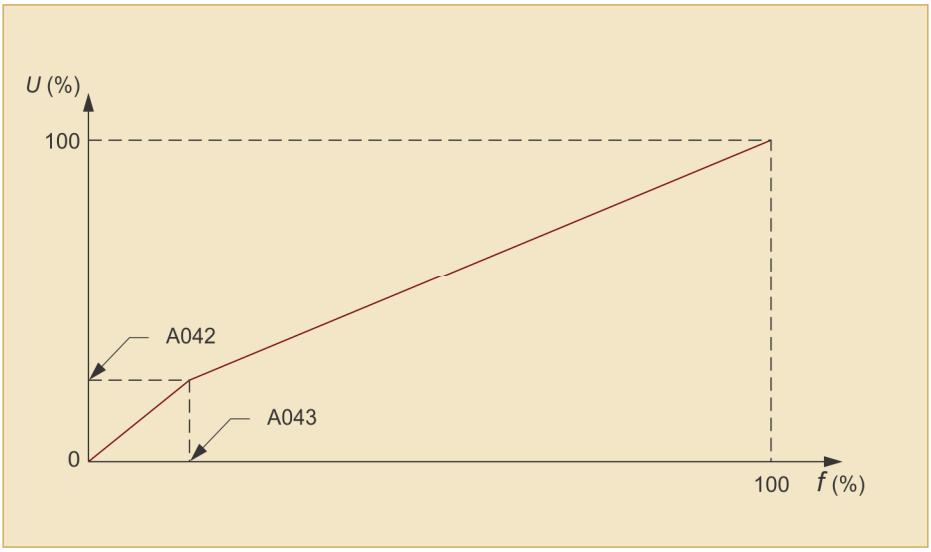


Figure 1-12. Torque boost.

The Torque boost selection function (parameter A041) lets you select between manual and automatic torque boost. Automatic torque boost is added to the V/f characteristics depending on the current load.

The torque boost functions are set using parameters A041, A042 and A043. The characteristics of these parameters are shown in Table 1-9.

Table 1-9. Characteristics of parameters A041, A042, and A043.

Parameter	Function	Value	DS
A041	*Torque boost selection*	00: Manual 01: Automatico	00
A042	*Manual torque boost voltage*	0 a 20% of output voltage	5.0
A043	*Manual torque boost frequency*	0 a 50% of base frequency	2.5

PROCEDURE OUTLINE

In the first part of this exercise, you will familiarize yourself with the setting of the acceleration and deceleration times.

In the second part, you will plot the linear and S-shape acceleration patterns.

In the third part, you will observe the torque boost characteristics. You will plot the output voltage versus output frequency curve with and without torque boost.

The Procedure is divided into the following sections:

- Equipment Required
- Basic setup
- Acceleration and deceleration ramps
- Acceleration characteristic
- Torque boost

PROCEDURE

Equipment Required

Refer to the Equipment Utilization Chart in Appendix A to obtain the list of equipment required for this exercise.

⚠ WARNING

The AC Power Supply provides high voltages. Do not change any AC connection with the power on.

Basic setup

1. Set up the circuit shown in Figure 1-8.

   Install the Brake Motor, Inertia Wheel, and Safety Guard.

2. Manually disengage the friction brake.

   Connect a voltmeter between terminals FV and FC on the AC Drive.

Acceleration and deceleration ramps

Perform the Energizing procedure.

Turn on the AC Power Supply.

3. Set the parameters of the AC Drive as follows:
   - Restore the default setting of the parameters by performing the Initialization procedure;
   - Select Terminal as Frequency reference selection function by setting parameter A001 to 01;
   - Set the AC Drive to display the output voltage by selecting parameter d013.

4. On the DC Drive, set the remote potentiometer to obtain 10.0 V dc on the voltmeter display.

   Determine the acceleration time by starting a chronometer as you set the AC Drive to the run mode, and stopping it when the data display indicates the maximum output voltage for your network (200 V or 400 V depending on your local network). Repeat the measurement to validate your result.

   Acceleration time:_____

10 s.

5. Does this correspond to the default setting of the Acceleration time function (parameter F002)?

   ❑ Yes ❑ No

Yes

6. Set the AC Drive to the run mode and wait for the motor to attain maximum speed.

   Determine the deceleration time by starting a chronometer as you set the AC Drive to the stop mode, and stopping it when the data display indicates 0 V. Repeat the measurement to validate your result.

   Deceleration time:_____

10 s.

7. Does this correspond to the default setting of the Decelaration time (F003)?

   ❑ Yes ❑ No

Yes

8. Familiarize yourself with the setting of acceleration and deceleration times by setting a 20.00 s acceleration time and a 15.00 s deceleration time.

   Test the operation of your circuit.

9. Turn off the AC Power Supply.

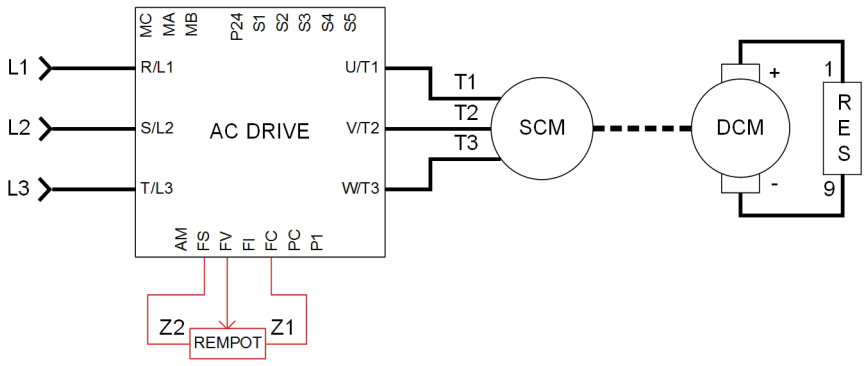
Acceleration characteristic

10. Remove the Safety Guard, and Inertia Wheel.

    Couple the DC Motor with the Brake Motor as described in Appendix D.

11. Connect the Starting Resistors module to the DC Motor as shown in Figure 1-13.

    The DC Motor with the Starting Resistors module acts as a load for the Brake Motor. Connect the resistors in series for maximum resistance.



LEGEND

AC DRIVE	=	THREE-PHASE AC DRIVE
DCM	=	DC MOTOR
REMPOT	=	REMOTE POTENTIOMETER (DC DRIVE POTENTIOMETER)
RES	=	LOAD RESISTOR
SCM	=	SQUIRREL CAGE MOTOR (BRAKE MOTOR)

Figure 1-13. Connect the Starting Resistors module to the DC Motor.

12. Turn on the AC Power Supply.

    Set the remote potentiometer REMPOT to obtain 10.0 V DC on the voltmeter display.

    Set the Acceleration time to 30 s by setting parameter F002 to 30.00.

    Make sure that the Acceleration pattern selection function (A097) is set to Line.

Set the AC Drive to display the output frequency by selecting parameter d001.

13. Measure the time taken by the AC Drive to attain 10 Hz by starting the chronometer as you set the AC Drive to the run mode, and stopping it when the AC Drive indicates 10 Hz. Repeat the measurement to validate your result.

Enter your result in the appropriate cell in the Linear column in Table -10.

Set the AC Drive to the stop mode.

Table 1-10. Linear and S-shape acceleration patterns.

Frequency Range	Time (s)	
	Acceleration Pattern	
	Linear	S-shape
0 a 10 Hz		
0 a 20 Hz		
0 a 30 Hz		
0 a 40 Hz		
0 a 50 Hz		
0 a 60 Hz (if applicable)		

Linear and S-shape acceleration patterns (120 V - 60 Hz network).

Frequency Range	TIme (s)	
	Acceleration Pattern	
	Linear	S - Shape
0 a 10 Hz	5.0	7.2
0 a 20 Hz	10.0	11.5
0 a 30 Hz	15.0	15.0
0 a 40 Hz	20.0	18.5
0 a 50 Hz	25.0	22.8
0 a 60 Hz	30.0	30.0

Linear and S-shape acceleration patterns (220/240 V - 50 Hz network).

Frequency Range	TIme (s)	
	Acceleration Pattern	
	Linear	S - Shape
0 a 10 Hz	6.0	7.8
0 a 20 Hz	12.0	12.7
0 a 30 Hz	18.0	16.8
0 a 40 Hz	24.0	21.7
0 a 50 Hz	30.0	30.0

Linear and S-shape acceleration patterns (220 V - 60 Hz network).

Frequency Range	Time (s)	
	Acceleration Pattern	
	Linear	S - Shape
0 a 10 Hz	5.0	6.4
0 a 20 Hz	10.0	11.0
0 a 30 Hz	15.0	15.0
0 a 40 Hz	20.0	18.2
0 a 50 Hz	25.0	22.8
0 a 60 Hz	30.0	30.0

14. Repeat the previous measurement for all frequency ranges shown in Table 1-10.

Enter your results in the appropriate cells in the Linear column in Table 1-10.

15. Set the AC Drive to the stop mode.

Set the Acceleration pattern selection function (A097) to 01 to select the S-shape acceleration pattern.

Set the AC Drive to display the output frequency by selecting parameter d001.

16. Repeat the measurements to fill out the empty cells of Table 1-10 with the S-shape acceleration pattern.

17. Set the AC Drive to the stop mode.

18. Plot the curves showing the linear and S-shape acceleration patterns in Figure 1-14. Place the Time values along the X-axis, and the Frequency values along the Y-axis.

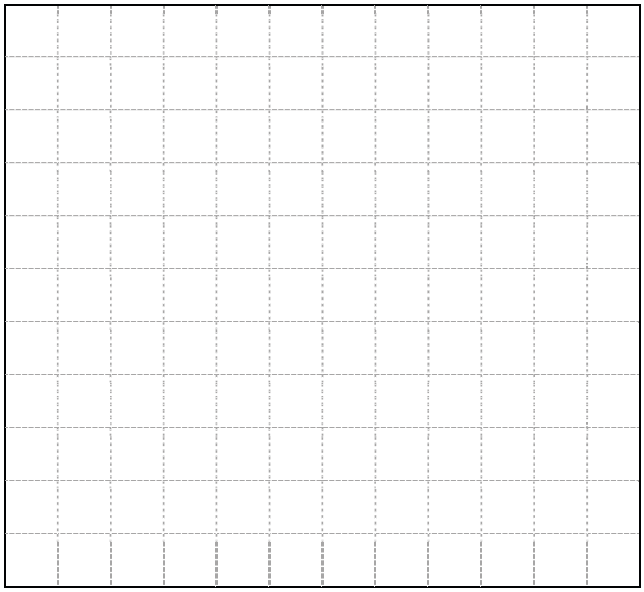


Figure 1-14. Linear and S-shape acceleration patterns.

19. Do your observations confirm that the S-shape acceleration pattern allows a motor to be started slowly?

❑ Yes ❑ No

Yes

20. Do your observations confirm the theory presented in the Discussion of this exercise?

❑ Yes ❑ No

Yes

21. Set the Acceleration pattern selection function to Line by setting parameter A097 to 00.

Torque boost

22. Make sure that the Torque boost selection function is set to Manual torque boost (parameter A041 = 00).

Set the Manual torque boost voltage function to 0% by setting parameter A042 to 0.

Set the Manual torque boost frequency function to 33% by setting parameter A043 to 33.

Set the AC Drive to display the output frequency by selecting parameter d001.

On the DC Drive, set the potentiometer to obtain 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

23. For all voltage setpoint values shown in Table 1-11, determine the corresponding output frequency displayed on the data display of the AC Drive. Enter your results in the appropriate cells in Table 1-11.

Table 1-11. Torque boost characteristics.

Setpoint		Output Voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Torque boost characteristics (120 V - 60 Hz network).

Setpoint		Output Voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1	6.7	22	35
2	12.8	43	69
3	19.5	65	104
4	25.5	85	119
5	31.5	105	133
6	37.6	125	147
7	43.6	145	161
8	49.8	166	177
9	56.0	186	191
10	60.0	198	198

Torque boost characteristics (220/240 V - 50 Hz network).

Setpoint		Output Voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1	5.1	40	66
2	10.2	82	132
3	15.4	122	198
4	20.5	164	236
5	25.7	206	264
6	30.8	246	292
7	36.00	288	322
8	41.1	330	350
9	46.3	362	362
10	50.0	362	362

Torque boost characteristics (220 V - 60 Hz network).

Setpoint		Output Voltage (V)	
Voltage (V)	f (Hz)	Without torque boost	With torque boost
1	6.0	40	64
2	12.0	78	128
3	18.0	118	192
4	24.0	160	230
5	30.0	200	256
6	36.0	238	286
7	42.0	280	314
8	48.0	318	346
9	54.0	362	372
10	60.0	380	380

24. Set the AC Drive to the stop mode.

Set the AC Drive to display the output voltage by selecting parameter d013.

Set the remote potentiometer to obtain 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

25. For all voltage setpoint values shown in Table 1-11, determine the corresponding output voltage displayed on the data display of the AC Drive.Enter your results in the WITHOUT TORQUE BOOST column in Table 1-11.

26. Set the AC Drive to the stop mode.

Set the Manual torque boost voltage function to 20% by setting parameter A042 to 20.

Set the AC Drive to display the output voltage by selecting parameter d013.

Set the remote potentiometer to obtai 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

27. For all voltage setpoint values shown in Table 1-11, determine the corresponding output voltage displayed by the data display on the AC Drive. Enter your results in the With torque boost column in Table 1-11.

28. Set the AC Drive to the stop mode.

29. Plot the curves with and without torque boost in Figure 1-15. Place the Frequency values along the X-axis, and the Output voltage values along the Y-axis.

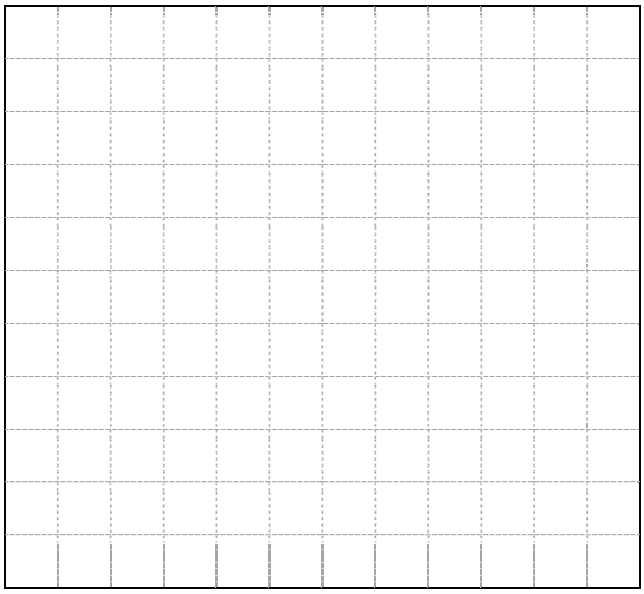


Figure 1-15. With and without torque boost characteristics.

30. At what frequency is the torque boost maximum?

Frequency where the torque boost is maximum: _____

33% of the base frequency.

31. Does the torque boost correspond to approximately 20% the output voltage at that frequency (33% of the base frequency)?

❑ Yes ❑ No

Yes

32. Turn off the AC Power Supply, disconnect the circuit, and return the equipment to the storage location.

CONCLUSION

In this exercise, you familiarized yourself with the acceleration and deceleration time settings. You plotted the curves showing the line and S-shape acceleration patterns.

You also experimented with the Torque boost function. You saw that it is possible to increase the voltage at a particular frequency to compensate for the voltage drop in the motor windings.

REVIEW QUESTIONS

1. Applications requiring slow start usually have

   a. short acceleration time.
   b. long acceleration time.
   c. short deceleration time.
   d. long deceleration time.

b

2. The purpose of an S-shape acceleration pattern is

   a. to combine soft starts and stops with high speeds when moving from a point to another.
   b. to combine rapid starts and stops with high speeds when moving from a point to another.
   c. to combine rapid starts and stops with low speeds when moving from a point to another.
   d. to combine soft starts and stops with low speeds when moving from a point to another.

a

3. Torque boost is applied at

   a. high frequencies.
   b. low frequencies.
   c. frequencies required by the load.
   d. None of the answers above is correct.

b

4. Torque boost is applied

   a. when the mass inertia moment of the connected load is high.
   b. to compensate for the voltage drop in the motor windings.
   c. beyond the normal V/f characteristic.
   d. All of the answers above are correct.

d

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