Industrial Maintenance

Motor Drives

Courseware Sample

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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

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.

Table of Contents

To the Instructor

- 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 and the quick start guide supplied with your training system (on a CD) may differ from the current default settings of the AC Drive.
- In order to keep the circuits as simple as possible, the use of the Emergency Button has not been integrated to all circuits in this manual. If you choose to use it, refer to Exercise 1-5 to learn how to stop the Brake Motor with a fault signal initiated from the Emergency Button. You may also use Relay K1 and a contactor to disconnect the AC Drive when the Emergency Button is pressed.
- 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

Student Manual

Ramp and Torque Boost

EXERCISE OBJECTIVE

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

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.

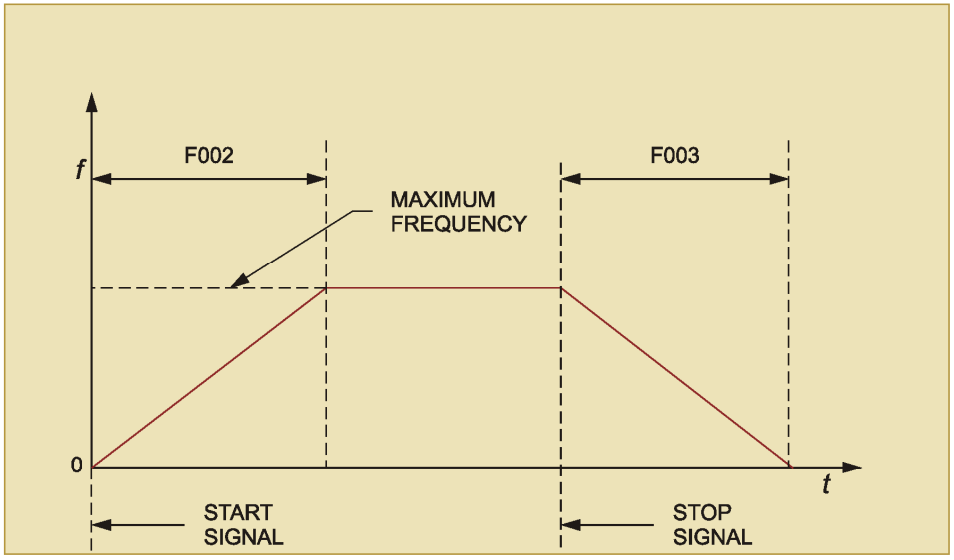


Figure 1-10. Acceleration/deceleration ramps.

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.

PARAMETER	FUNCTION	VALUE	DS
F002	*Acceleration time*	0.01 to 3000 s	10.00
F003	*Deceleration time*	0.01 to 3600 s	10.00
A097	*Acceleration pattern selection*	00: Line 01: S-shape curve	00
A098	*Deceleration pattern selection*	00: Line 01: S-shape curve	00

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

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 pattern, its rate of change until it reaches full speed, or comes to a complete stop, is linear. See Figure 1-11.

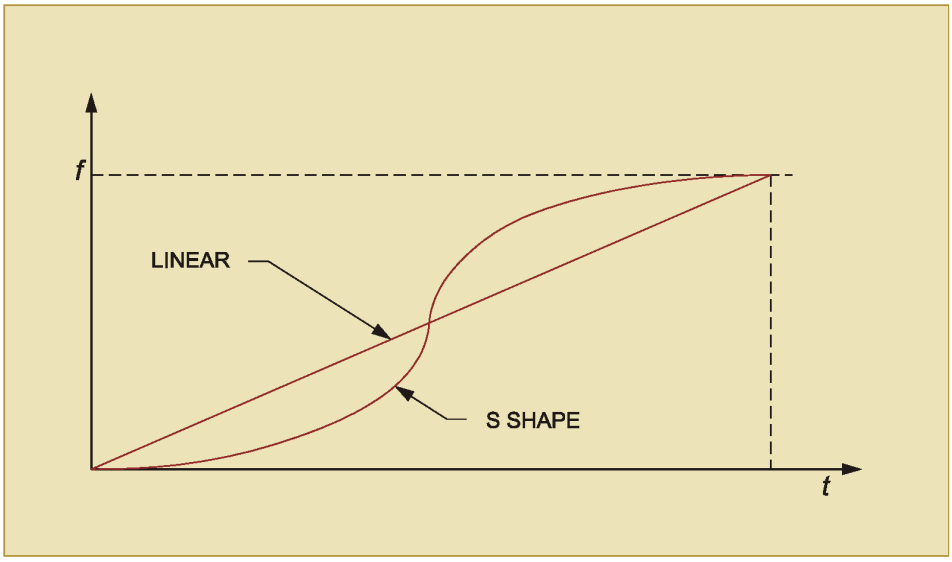


Figure 1-11. Linear and S-shape patterns during acceleration.

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 of 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.

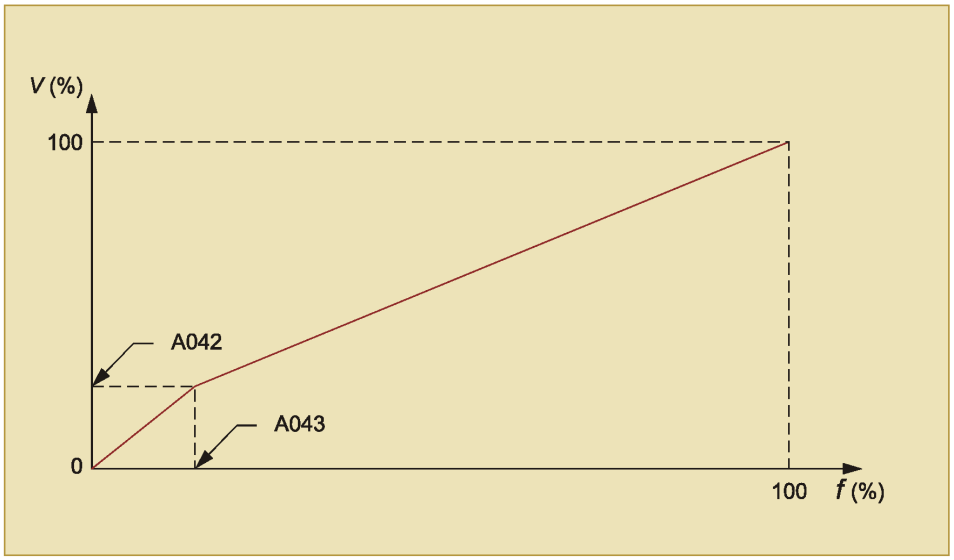


Figure 1-12. Torque boost.

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.

PARAMETER	FUNCTION	VALUE	DS
A041	*Torque boost selection*	00: Manual 01: Automatic	00
A042	*Manual torque boost voltage*	0 to 20 % of output voltage	5.0
A043	*Manual torque boost frequency*	0 to 50 % of base frequency	2.5

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

Procedure Summary

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.

EQUIPMENT REQUIRED

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

PROCEDURE

⚠ WARNING

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

Basic setup

☐ 1. Perform the Basic Setup and Lockout/Tagout procedures.

Acceleration and deceleration ramps

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

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

☐ 4. Manually disengage the friction brake.

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

Perform the Energizing procedure.

☐ 5. 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.

☐ 6. 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 results.

Acceleration time: _____

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

☐ Yes ☐ No

☐ 8. 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 results.

Deceleration time: _____

☐ 9. Does this correspond to the default setting of the *Declaration time* (F003)?

☐ Yes ☐ No

☐ 10. 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.

☐ 11. Turn off the Lockout Module.

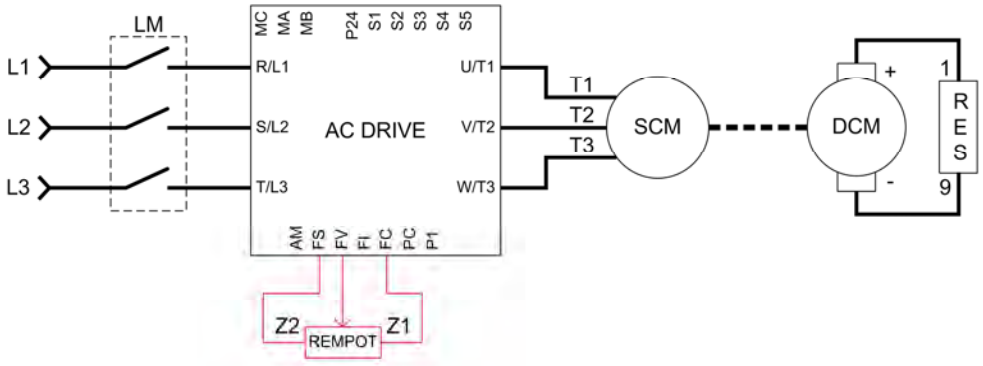
Acceleration characteristic

☐ 12. Remove the Safety Guard, and Inertia Wheel.

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

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

Note: *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
LM	=	LOCKOUT MODULE
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.

☐ 14. Turn on the Lockout Module.

Set the remote potentiometer 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.

☐ 15. 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 measurements to validate your results.

Enter your result in the appropriate cell in the Linear column in Table 1-10.

Set the AC Drive to the stop mode.

FREQUENCY RANGE	TIME (s)	
	ACCELERATION PATTERN	
	Linear	S-shape
0 to 10 Hz		
0 to 20 Hz		
0 to 30 Hz		
0 to 40 Hz		
0 to 50 Hz		
0 to 60 Hz (if applicable)		

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

☐ 16. 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.

☐ 17. 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.

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

☐ 19. Set the AC Drive to the stop mode.

☐ 20. 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.

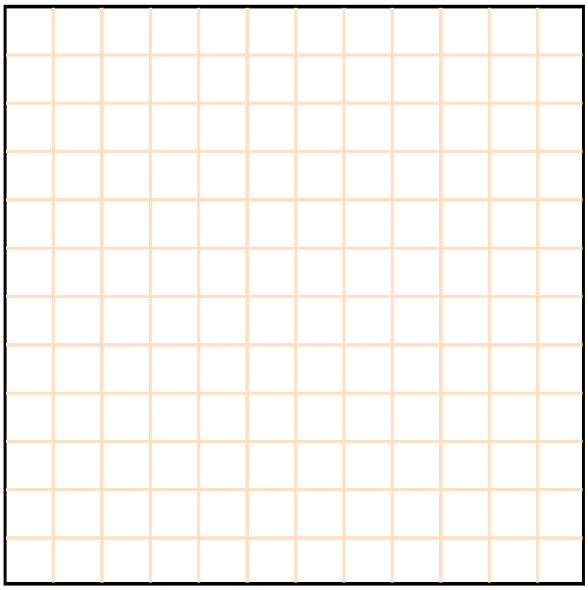


Figure 1-14. Linear and S-shape acceleration patterns.

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

☐ Yes ☐ No

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

☐ Yes ☐ No

☐ 23. Set the *Acceleration pattern selection* function to Line by setting parameter A097 to 00.

Torque boost

☐ 24. 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.

☐ 25. 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.

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

Table 1-11. Torque boost characteristics.

☐ 26. 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.

☐ 27. 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.

☐ 28. 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 obtain 0.0 V dc on the voltmeter display.

Set the AC Drive to the run mode.

☐ 29. 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.

☐ 30. Set the AC Drive to the stop mode.

☐ 31. 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.

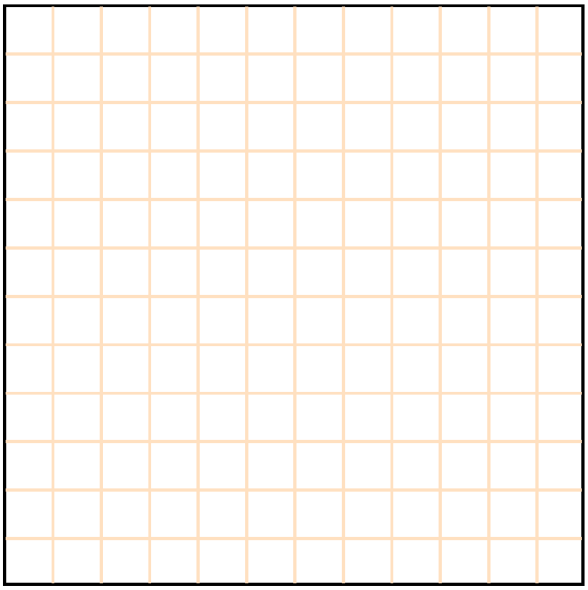


Figure 1-15. With and without torque boost characteristics.

☐ 32. At what frequency is the torque boost maximum?

Frequency where the torque boost is maximum: _____

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

☐ Yes ☐ No

☐ 34. Turn the individual power switch of the AC Power Supply off, 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.

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.

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.

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.

Sample

Extracted from

Instructor Guide

Volts per Hertz Characteristics

ANSWERS TO PROCEDURE STEP QUESTIONS

☐ 6. Forward.

☐ 8. No. The potentiometer is disabled by parameter A001.

☐ 10. Yes.

☐ 13. Yes.

☐ 15. Constant torque.

☐ 17.

V/f CHARACTERISTICS				
SETPOINT		n (r/min)	OUTPUT VOLTAGE (V)	
VOLTAGE (V)	f (Hz)		CONSTANT TORQUE	REDUCED TORQUE
1	6	207	32	14
2	12	399	52	22
3	18	594	73	38
4	24	783	92	54
5	30	963	111	72
6	36	1146	131	95
7	47	1320	149	120
8	48	1512	170	151
9	54	1701	190	181
10	60	1794	200	200

Table 1-7. V/f characteristics (120 V – 60 Hz network).

V/f CHARACTERISTICS				
SETPOINT		n (r/min)	OUTPUT VOLTAGE (V)	
VOLTAGE (V)	f (Hz)		CONSTANT TORQUE	REDUCED TORQUE
1	5	148.5	58	26
2	10	318.6	78	42
3	15	478.8	136	66
4	20	635.2	172	98
5	25	792	212	134
6	30	951	250	178
7	35	1105	288	226
8	40	1259	376	288
9	45	1394	364	342
10	50	1492	380	380

Table 1-7. V/f characteristics (220/240 V – 50 Hz network).

V/f CHARACTERISTICS				
SETPOINT		n (r/min)	OUTPUT VOLTAGE (V)	
VOLTAGE (V)	f (Hz)		CONSTANT TORQUE	REDUCED TORQUE
1	6	178	58	26
2	12	360	96	42
3	18	541	134	66
4	24	725	172	96
5	30	903	208	132
6	36	1084	246	177
7	42	1267	284	224
8	48	1435	326	280
9	54	1671	360	334
10	60	1791	380	380

Table 1-7. V/f characteristics (220 V – 60 Hz network).

☐ 22. Yes.

☐ 23. Yes.

ANSWERS TO REVIEW QUESTIONS

1. c; 2. b; 3. b; 4. a; 5. c.

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