Starting duty only synchronous transfer systems

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Abstract

Synchronous transfer drive systems provide flexibility in pipeline and pumping applications. Within a pipeline, pressure to a system can be increased in stages, reducing mechanical shock to the pipeline. Pumping stations can closely regulate pumping capacity required by bringing pumps online and offline. By utilizing a single adjustable frequency drive (AFD), overall cost can be reduced, although control complexity increases depending on the specific system requirements.

In a pipeline system or gas compression facility, significant cost savings can be realized by sizing the drive for "starting duty only." The drive is sized to start the motor under reduced load, synchronize the AFD output to the utility line, transfer the motor to the line, and only then is the compressor loaded. The same principle can be applied to soft or weak power systems that cannot support an across-the-line start and where continuous AFD speed regulation is not required. Pump or fan driven loads also benefit from this starting method. A drive size reduction of approximately 50% is obtained through a "starting duty only" rating with further reduction if exact motor and load parameters are known.

Starting study example

To correctly size the AFD for this application, knowledge of motor and driven load torque curves, motor and driven load inertia, and acceleration times are required. These parameters are used to calculate the starting of motor and driven load. The data shown in **Table 1** and **Table 2** is referenced in this example. The driven load is a reciprocating natural gas compressor.

Table 1. Motor data

Motor data		
1000	Horsepower	Rated
1165	RPM	Rated
132	Amperes	Full load
0.9	Power factor	Full load
4000	Volts	Rated
2748	lb-ft^2	Combined WK^2

Table 2. Load data

% speed	Full torque p.u.	Low torque p.u.
0	0.38	0.38
20	0.10	0.10
40	0.19	0.19
60	0.38	0.25
80	0.62	0.30
90	0.76	0.35
95	0.86	0.38
100	0.95	0.40

Motor and load torque vs. speed requirements are illustrated in **Figure 1**. The time required to bring the compressor up to full speed is approximately 9 seconds. If the compressor load can be reduced during the acceleration, the motor and drive torque requirements are significantly reduced. It is important to note the load breakaway torque is not reduced but the torque requirement curve starts to diverge at around 40% of motor base speed.

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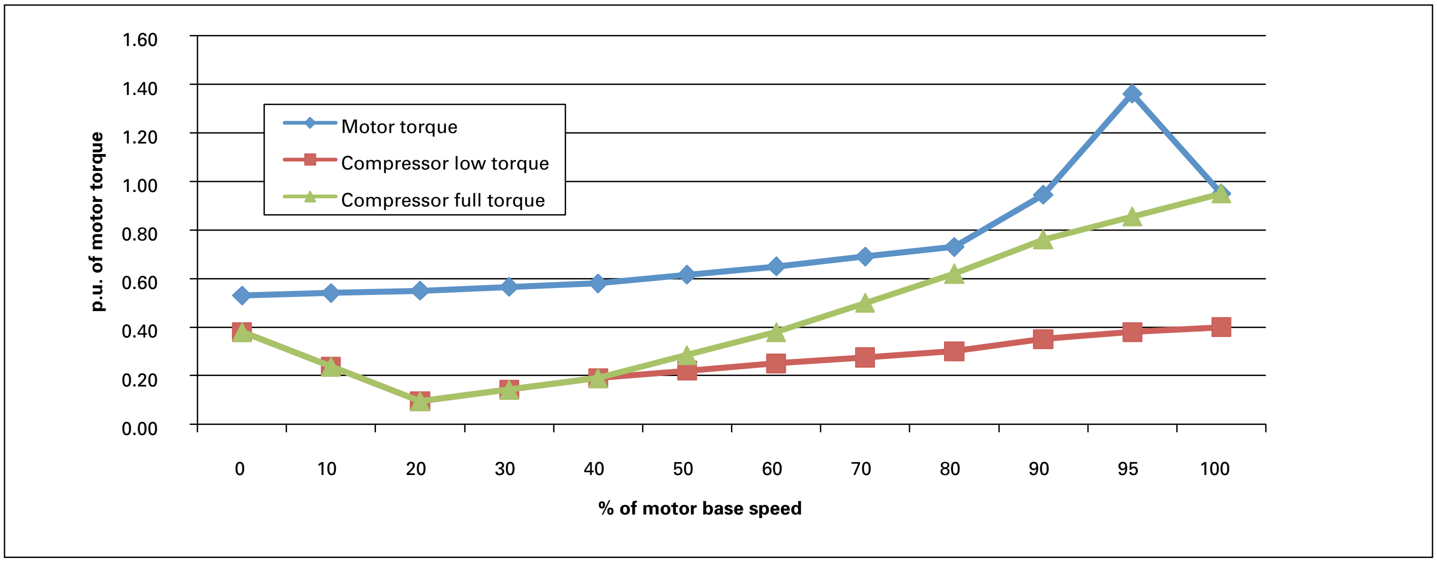

Figure 1. Motor start

A fully rated drive can start the motor in less time because the V/Hz ratio is kept constant, allowing the motor to generate 100% torque through the speed range. A "starting duty only" rated drive can be sized based on the torque and horsepower demanded by the motor from a reduced load on the compressor while accelerating from zero speed to 60 Hz. The steps outlined show how the torque influences the inverter and transformer sizing.

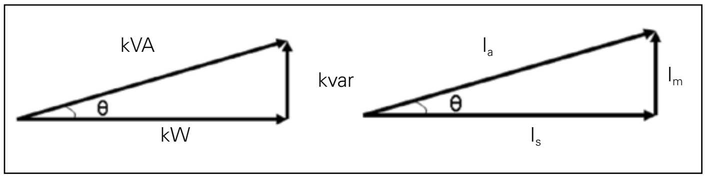

Figure 2. Power triangle

The first step is to determine the motor magnetizing (I_m) current requirements. The drive must be able to supply magnetizing current and it is assumed to be constant throughout the speed range (note that Motor No Load Current can be used if known). Because magnetizing current is approximately 90 degrees out of phase with the torque producing current (I_s), I_a is the total current required by the drive. The calculated motor magnetizing current is:

$$I_m = I_a \times \sin(\cos^{-1}(0.9)) = 132\ A \times 0.436 = 57.5\ A$$

Equation 1

The torque producing current to generate full motor torque is 120.1 A.

$$I_s = I_a \times pF = 132\ A \times 0.91 = 120.1\ A$$

The peak torque is 0.4 p.u. for a reduced loaded compressor requiring a motor current of 48.0 A.

$$I_s = 120.1\ A \times 0.4 = 48.0\ A$$

Equation 2

An AFD must be selected that is able to deliver the total current (I_a):

$$I_a = \sqrt{48\ A^2 + 57.5\ A^2} = 74.9\ A$$

Equation 3

A typical 600 hp, 4160 V AFD is capable of 76 A continuous with 110% overload factor for 1 minute every 10 minutes. This drive is selected because the overload is needed only at the low speed (break away torque) and full speed (peak torque).

Table 3. AFD data

Drive data		
4160	Volts	Rated
600	Horsepower	Rated
76	Amperes	Full load
84	Amperes	110% overload

The p.u. available torque producing current the AFD is capable of is:

$$I_{s,AFD} = \sqrt{84\ A^2 - 57.5\ A^2} = 61.2\ A$$

$$I_{s,p.u.} = \frac{61.2\ A}{120.1\ A} = 0.51$$

Equation 4

The torque developed by the motor with the "starting duty only" drive is about 50% of a fully rated drive.

The next step is to determine how quickly the AFD is able to accelerate the unloaded compressor. By summing the acceleration time between 10% base speed increments from 0 speed to full speed, the total acceleration time is calculated at 13.4 seconds.

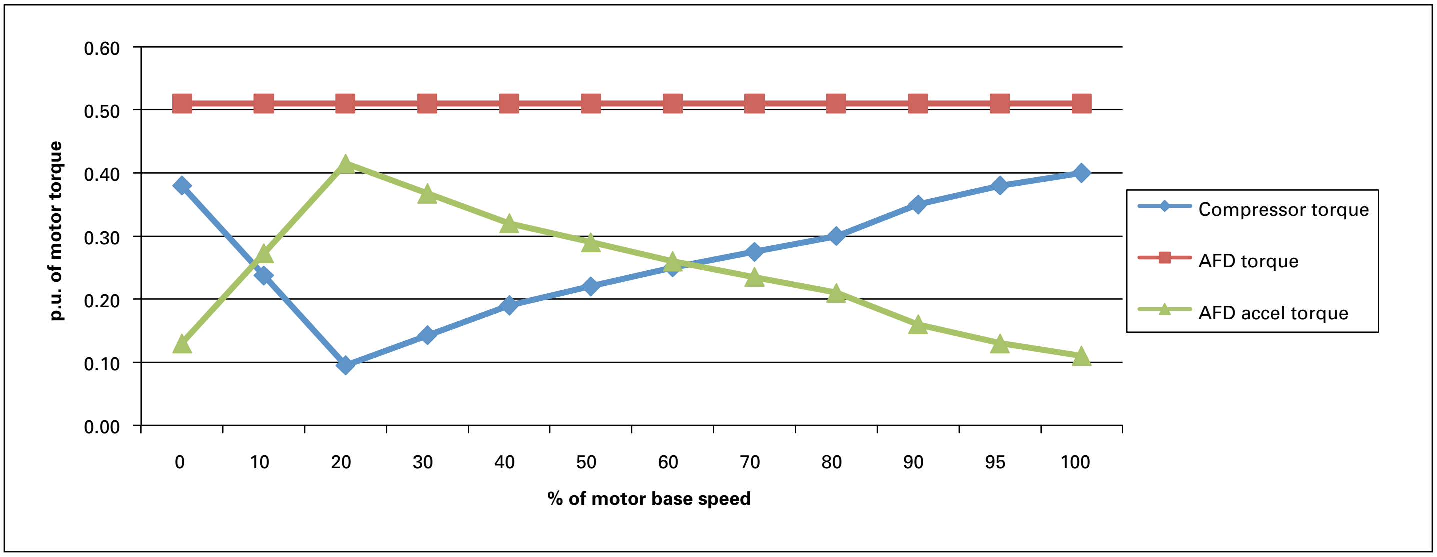

Figure 3. Starting duty AFD

Table 4. Starting duty AFD data

% speed	RPM	Motor torque p.u.	Compressor low torque p.u.	Compressor full torque p.u.	AFD accel torque p.u.	AFD torque p.u.	Accel time (sec)
0	0	0.53	0.38	0.38	0.13	0.51	1.774
10	117	0.54	0.24	0.24	0.27	0.51	0.847
20	233	0.55	0.10	0.10	0.42	0.51	0.556
30	350	0.57	0.14	0.14	0.37	0.51	0.628
40	466	0.58	0.19	0.19	0.32	0.51	0.721
50	583	0.62	0.22	0.29	0.29	0.51	0.795
60	699	0.65	0.25	0.38	0.26	0.51	0.887
70	816	0.69	0.28	0.50	0.24	0.51	0.982
80	932	0.73	0.30	0.62	0.21	0.51	1.098
90	1049	0.94	0.35	0.76	0.16	0.51	0.721
95	1107	1.36	0.38	0.86	0.13	0.51	0.887
100	1165	0.95	0.40	0.95	0.11	0.51	
						Estimated time (sec)	**9.9**

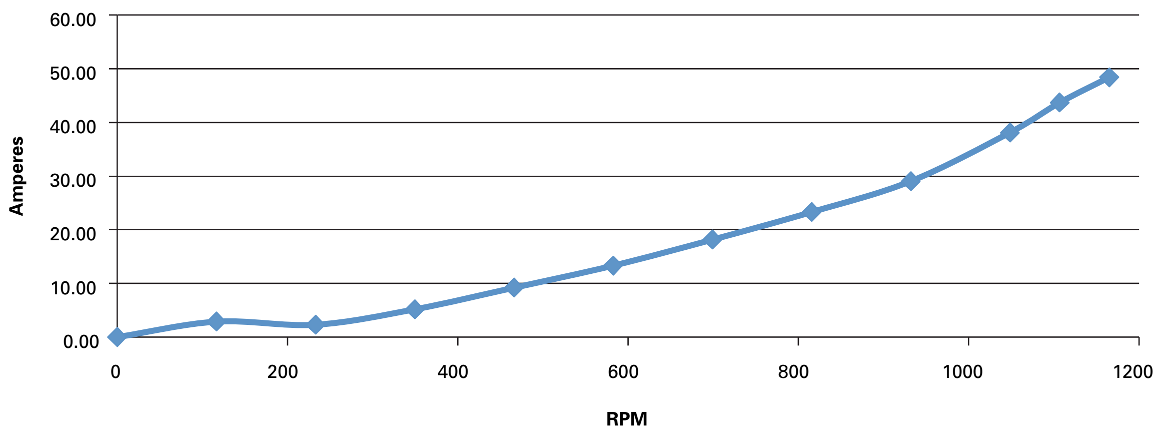

Figure 4. AFD input amperes

If this acceleration time is acceptable for the compressor process, the drive inverter can be used. The drive transformer can also be optimized by calculating the required horsepower to accelerate the motor. Accounting for the efficiency of the AFD, the peak input is 460 hp. Because the acceleration time is less than the rated overload duration, the inverter is able to handle the load. A 500 hp AFD that is capable of 76 A inverter output can be selected for this motor starting application.

The impact to the power system while accelerating a motor on an AFD is visualized (see **Figure 4**). This plot shows the AFD input amperes as the motor is accelerated to full speed with reduced load. The input power factor of the AFD is 0.97 through the speed range with an estimated efficiency of 97%.

Footprint, weight, and drive sizing is significantly reduced and are the biggest advantages of this type of system. The selected 500 hp drive is 36% narrower than a standard 1000 hp option; therefore, space is saved. The rating requirement has decreased 50% and the cost has reduced approximately 18%.

Conclusion

The ability to run the compressor under reduced load requires a reduced size AFD in this synchronous transfer system. The rating requirement is reduced 50% and is 36% narrower. This saves on total cost and floor space used in the building. However, in order to properly size the drive for "starting duty only," motor and load information was required. Also, the drive must be able to handle the magnetizing current of the motor regardless of load. It is important that the process control of the compressor, pump, fan, etc., load is regulated to ensure the motor load does not exceed the AFD inverter and horsepower capacity.

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