

Section 7 VSD Control

Overview of VSD / VFD / AC Induction motors 7-1

The LMV52 features an integrated, closed loop VSD (Variable Speed Drive) controller that is typically used to vary the speed of the combustion air blower. Since the LMV52 has a VSD control, it is capable of controlling many different types of drives and Motors. Both DC drives and motors as well as AC drives and motors can be controlled with the LMV52.

By far the most common type of drive and motor that is used with the LMV52 VSD control is the VFD (Variable Frequency Drive) driving an AC induction motor. This section will focus on the unique characteristics of a VFD driving an AC induction motor and will also explain the effects of a centrifugal blower on this arrangement. Throughout this section the terminology VSD control is used since it is a more generic term, and is also the terminology used on the AZL52. A VFD is basically a specific type of VSD.

Most modern VFD operate in basically the same way. They take 3 phase AC power, rectify this power to DC, and then they output pulsed DC to an AC motor. Thus, pulsed “square wave” DC is used to approximate a sine wave on each of the motors three phases. This approximation of a sine wave is adequate to run the motor. As one might expect, the frequency and the amplitude of the square waves is controlled by the VFD microprocessor, and can be regulated to control the speed of a synchronous motor.

The motors that are used on most burner blowers are AC induction motors. These motors are called induction motors since they do not have slip rings or brushes to power the electromagnets in the rotor. Instead, AC induction motors use principles of induction to power the electromagnets in the rotor. Induction is very attractive since this means that there are no slip rings or brushes to wear out, and the only part of the AC induction motor that really wears are the rotor (shaft) bearings. The slight disadvantage of using induction motors is a phenomenon called slip. In the absence of slip, an AC motor having two poles per phase would turn at exactly 3600 RPM when it was supplied with 60 Hz (Hertz) three phase power. A four pole per phase AC motor would turn at exactly 1800 RPM @ 60 Hz. These two hypothetical “non slip” motors are called synchronous motors since they exactly synchronize themselves with the frequency of power they are supplied with.

In contrast to no-slip synchronous motors, AC induction motors have slip so they are only semi-synchronous. Furthermore, the amount of slip depends upon how heavily the motor is loaded. Slip will increase as the motor’s load increases. For example, a real life 2 pole 3 phase AC induction motor fed 60 Hz 3 phase power under no load will turn very close to 3600 RPM, most likely in the neighborhood of 3585 RPM. As load is applied to the motor shaft, the RPM will drop (slip will increase) and the amperage on all three phases will increase. The same 2 pole three phase AC induction motor that was turning 3585 RPM @ 60 Hz power may drop down to 3510 RPM or lower when subjected to heavy loads even though it is still being fed 60 Hz power. For a fixed motor input frequency, slip can be thought of as a spring that compresses when loaded and the height of the spring can be thought of as the RPM of the motor.

In summary, a VFD can control the amplitude and frequency of the simulated three phase power (pulsed, square wave DC) that they produce very accurately. Unfortunately, this accuracy does not translate into accurate control of the motor RPM due to induction motor slip. To further distort the situation, these AC induction motors typically drive centrifugal blowers which have highly un-linear characteristics. The horsepower requirement of centrifugal blowers increases by the cube (x^3) of the speed ratio, so the load on the motor

and therefore the slip increase dramatically with increasing blower RPM. As one may conclude these factors can lead to inaccuracies in blower speed and therefore air delivery to the burner. These reasons, as well as the element of safety that verifying the speed of the blower ensures, are why the LMV52 has a closed loop VSD control.

Another point worth mentioning is the effect that accelerating and de-accelerating the blower wheel has on the VFD. Most blower wheels, especially on larger burners tend to be heavy and have a large moment of inertia. Since this is the case, faster VFD and LMV52 ramp rates require more VFD power and braking capability, just like heavier trucks need larger engines and brakes to achieve the same acceleration and deceleration as lighter trucks. Setting ramp rates will be discussed later in this section.

Introduction and Principle of Operation 7-2

The LMV52 VSD controller is typically used to vary the speed of the combustion air blower. In most cases, the blower RPM is decreased at low fire and increased to maximum or near maximum when the burner is at high fire. The primary advantages of this capability are less noise and reduced power consumption especially at low to mid fire.

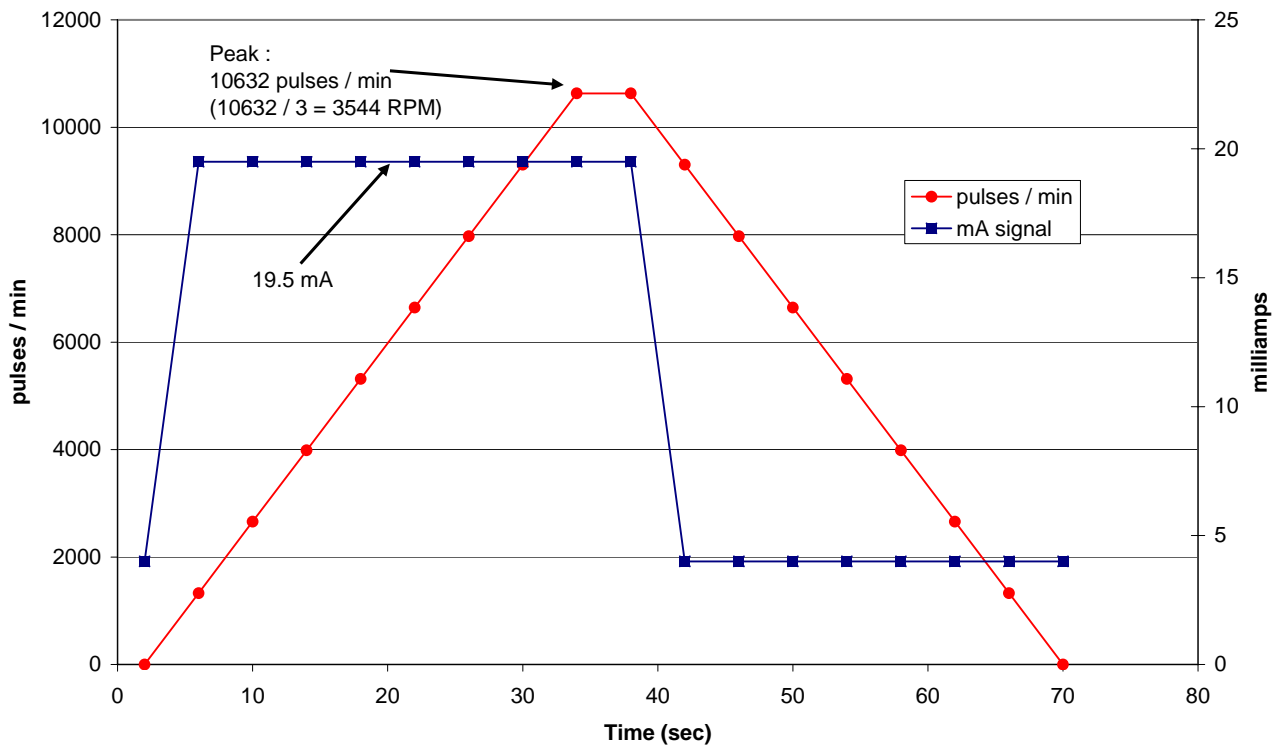
As previously mentioned the VSD control in the LMV52 is an active closed loop control. A speed wheel and sensor mounted to the motor / blower shaft provides a pulse feedback to the LMV52 so that the speed of the blower can be constantly monitored and corrected if necessary. Since the speed wheel is asymmetrical, the LMV52 can also determine the direction of blower rotation.

The VSD control in the LMV52 regards the VSD / motor / speed wheel combination much the same way as the LMV5 regards an air or fuel actuator. With an air or fuel actuator, the LMV5 sends the actuator a command over the CANBus to move to a certain position. The actuator then rotates, and this change is verified and fine tuned with the feedback potentiometer that is mounted on the actuator's shaft. Similarly, the LMV52 VSD control sends out a command in the form of an analog signal (typically 4-20mA) to a VSD. The VSD / blower motor then increases or decreases speed in accordance with the 4-20mA signal and the change is verified and fine tuned using the speed wheel feedback that is mounted on the blower shaft. In either case if the feedback from the potentiometer or speed wheel is out of range a lockout will result.

The SQM4 actuators are calibrated (standardized) before they leave the factory. During this process, the output of the shaft mounted potentiometer is matched to the position of the actuator shaft. Thus a relationship of ohms per degree is established. Much like the SQM4 actuator, the VSD / motor combination must be calibrated to the LMV52 before they are put into operation. This procedure is called *Standardization* and involves the LMV52 ramping the VSD / motor combination up, automatically recording the peak RPM, and ramping the VSD back down. This establishes a linear milliamp to pulse relationship that is correct for the VSD motor combination that is being used with the LMV52 VSD control. For the standard three fingered speed wheel, three pulses per revolution are produced. For the special six fingered speed wheel, six pulses per revolution are produced. The standardization process for a three fingered speed wheel is illustrated in Figure 7-2.1. The process for the six fingered speed wheel is the same, except that the pulses per minute would be divided by six instead of three to figure out the RPM. Typically, the six fingered speed wheel is only used where the blower RPM would be less than 300 RPM. Absolute minimum RPM for operation is 170 RPM with the six fingered speed wheel.

Figure 7-2.1 Typical Standardization

Time (sec)	LMV52 output to VSD (mA)	Blower Shaft Speed (RPM)	Feedback from speed wheel (pulses / min)	VFD output Freq. (Hz)
2	4	0	0	0
6	19.5	443	1329	7.5
10	19.5	886	2658	15.0
14	19.5	1329	3987	22.5
18	19.5	1772	5316	30.0
22	19.5	2215	6645	37.5
26	19.5	2658	7974	45.0
30	19.5	3101	9303	52.5
34	19.5	3544	10632	60.0
38	19.5	3544	10632	60.0
42	4	3101	9303	52.5
46	4	2658	7974	45.0
50	4	2215	6645	37.5
54	4	1772	5316	30.0
58	4	1329	3987	22.5
62	4	886	2658	15.0
66	4	443	1329	7.5
70	4	0	0	0.0



Note: The standardization time of 70 seconds was used as an example, but it may be longer or shorter depending upon VSD / LMV5 ramp rates.

The goal of the standardization process is to find the pulses per minute and therefore blower RPM that corresponds to a 95% (19.5 mA) signal to the VSD. Once the LMV52 detects the peak motor RPM associated with 19.5mA, it linearly scales the motor RPM to the 4-19.5 mA signal. More specifically for the standardization in Figure 7-2.1, it associates 4 mA with 0 RPM and 19.5mA with 3544 RPM and performs a two-point linear interpolation.

If the standardization shown in Figure 7-2.1 were performed on a LMV52, and parameter “*Num Puls per R*” is set to 3 for a three fingered speed wheel, the LMV52 would automatically set parameter “Standardized Sp” to 3544 RPM. Manual setting of the “*Standardized SP*” parameter is possible but not recommended.

The useful result of standardization is a base line for LMV52 VSD control that is custom tailored to the VSD / motor that is being used with the LMV52. This base line has three main components: VSD Control %, Blower Shaft RPM, and Output mA Signal to VSD. During normal operation, the LMV52 can increase or decrease the milliamp signal to the VSD to maintain a certain RPM. There are limits on how much correction the milliamp signal to the VSD can be altered off of the base line, in response to a RPM that is too low or too high.

Figure 7-2.2 illustrates the results of the typical standardization performed in Figure 7-2.1. Figure 7-2.2 also shows the approximate correction limits of how much the VSD control's output signal can be altered in response to a measured RPM that is too low or too high.

Figure 7-2.2 Results of Standardization, VSD Control Output Signal Variation

Results of Standardization			Approximate Correction Limits	
Standardized VSD Control %	Standardized Blower Shaft RPM	Standardized Output mA Signal to VSD	Maximum signal to correct for low RPM (mA)	Minimum signal to correct for high RPM (mA)
10	355	5.6	7.92	4.05
15.0	533	6.4	8.69	4.82
20.0	710	7.1	9.46	5.59
25.0	888	7.9	10.24	6.37
30.0	1066	8.7	11.01	7.14
35.0	1244	9.5	11.78	7.91
40.0	1421	10.2	12.55	8.68
45.0	1599	11.0	13.33	9.46
50.0	1777	11.8	14.10	10.23
55.0	1954	12.5	14.87	11.00
60.0	2132	13.3	15.64	11.77
65.0	2310	14.1	16.41	12.54
70.0	2488	14.9	17.19	13.32
75.0	2665	15.6	17.96	14.09
80.0	2843	16.4	18.73	14.86
85.0	3021	17.2	19.50	15.63
90.0	3199	18.0	20.28	16.41
95.0	3376	18.7	21.05	17.18
100.0	3554	19.5	21.82	17.95

After viewing Figures 7-2.1 and 7-2.2, the keen observer most likely notices some numbers that do not make immediate sense. Specifically, these numbers are the milliamp signal used for standardization, the 60 Hz VFD output frequency corresponding to 19.5 mA input, and a signal greater than 20 mA. The next couple of paragraphs will explain why these and other numbers associated with the VSD have the values that are shown.

When standardized, the LMV52 VSD control only outputs 19.5 mA to the VFD and the resulting motor RPM (read by the speed wheel) is recorded for the standardization. The reason 19.5 mA is output for the standardization instead of 20mA is so that there is additional room to increase the signal to the VFD if the motor RPM drops due to increased motor load. For similar reasons, the VFD should be spanned so that 4mA input signal = 0 Hz and a 20mA input signal = 62.5 or 63 Hz. This means that at a 19.5 mA signal to the VFD, the frequency output of the VFD should be about 60 Hz. This is all done in an effort to have some reserve built into the control system so that the blower can make rated speed under all environmental conditions.

The VSD control appears as another actuator when commissioning the fuel air ratio curves. The only main difference is that the SQM4 actuators are in degrees and have a range of 0 to 90 degrees, while the VSD control is in percent and has a range of 10 to 100 percent. When a particular percentage of VSD is saved for a point, the RPM corresponding to that percentage is maintained by varying the milliamp signal to the VFD. The limits of this control range are shown in Figure 7-2.1. On the top end, the LMV52 VSD control will output up to almost 22 mA if the blower RPM is low at 100% load. However, this typically does not happen if the VFD is spanned as described above. If the upper control range limit is reached and the blower RPM is still low, a message will be displayed on the AZL that states “*Fan speed not reached*”. If the lower control range limit is reached and the blower RPM is still high, a message will be displayed on the AZL that states “*Control range limitation VSD Module*”. Fan speed not reached results in an immediate lockout, and control range limitation VSD Module will result in a lockout if the blower RPM does not come into range in about 5 seconds after the warning is displayed.

Step by Step Commissioning of the VSD Control 7-3

After verifying that the wiring from the LMV52 to both the speed wheel and the VFD are correct and all system components are grounded properly the VSD can be set-up, and commissioned.

Note: Verify that the arrow on the speed wheel points in the desired direction of rotation. If not, the wheel can be turned over and re-mounted so that the speed wheel arrow is in the correct direction.

1. Set / Check the relevant parameters in the LMV52. All parameters related to the LMV52 VSD control are outlined in Section 4-2 of the Quick Start Guide. The following parameters should be checked for most applications.
 - a. Under *Ratio Control > Gas / Oil settings > VSD*, activate the VSD. If the burner is dual fuel, the VSD must be activated for gas and oil. Also set the air actuator to “*air influen*”.
 - b. Under *Ratio Control > Times*, set the ramp times. Both *OperatRampMod* and *TimeNoFlame* should be set to at least 10 seconds longer than the ramp rate programmed into the VFD. Typically the VFD is 30 seconds, so these should be set to 40 seconds.

- c. Under *VSD Module > Configuration > Speed > Num Puls per R*, change *Num Puls per R* to 6 if a six fingered speed wheel is used. The default setting is 3.
 - d. Under *VSD Module > Configuration > Speed > Setpoint Output*, verify that *Setpoint Output* signal is set to 4-20mA instead of 0-20mA.
2. Set / Check the relevant VFD parameters. Many parameters must be set in the VFD for the specific application such as motor HP, max / min motor speed, number of motor poles, service factor, etc.. Although the names of the actual VFD parameters may change by manufacturer, VFD settings specific to using a LMV52 VSD control with a VFD are:
 - a. Span the VFD input signal so that 4mA = 0 Hz and 20mA = 62.5 or 63 Hz.
 - b. Set the VFD so that it starts and runs on a contact closure. The dry contact that closes in the LMV52 to signal a run is on terminals X73.1 and X73.2.
 - c. Set the VFD ramp rate so that it is able to ramp more quickly than the LMV52. A ten second differential (as explained in step 1) works well for most applications. Also note that faster VFD ramp rates will generate higher amperage for both the motor and the VFD.
 - d. Set the VFD so that it sends an alarm signal to the LMV52 in the event of a VFD problem, such as over-current. The 12-24 VDC alarm input is terminal X73.3 on the LMV52.
 - e. Make sure that no PID loops or filtering exist on the VFD input signal, so that 19.5 mA input directly produces a 60 Hz VFD output, an 11.7 mA input directly produces a 30 Hz output etc... The LMV52 VSD control already contains an application-tuned PID loop, and “stacked” PID loops do not provide accurate control. In short, the VFD needs to be programmed as a slave device.
3. After both the LMV52 and the VFD are wired and configured properly, then the standardization can be performed. As was mentioned earlier, this is when the LMV52 “learns” the specific characteristics of VFD / motor that is connected to. This procedure is automatic, but does have some prerequisites. These are:
 - a. If working on an un-configured LMV52, ensure that the *Burner ID* is set, the fuel train is defined, the actuators are addressed and rotating the correct direction and that the actuator special positions are set. The pre-purge position of the air actuator should be close (+/- 15 degrees) to the expected high fire air actuator position.
 - b. Make sure The LMV52 safety loop is energized (closed) including the burner flange section. The safety loop can be open in Phase 12 and not cause an alarm, but the LMV52 will not *Standardize* if the safety loop is open. Standardization is possible even while the LMV52 is in an alarm condition, as long as the alarm is not due to an open safety loop.
 - c. Under *VSD Module > Configuration > Speed > Standardization*, activate the *standardization*. The air actuator should open to the purge position and the VFD / blower motor should ramp up and then ramp back down. After the ramp down is complete, *deactivate standardization*.
 - d. Parameter “*StandardizedSP*” should read close to full speed RPM of the blower motor. For most 3600 RPM blowers, it should be 3500 +/- 100 RPM.
 - e. If the LMV52 does not have O2 trim, set the air actuator back to *activated* instead of “*air influen*”.
4. The LMV52 VSD control set-up is now complete, and the blower speed can be set at each *special position* and fuel air ratio control point. (Combustion curve)