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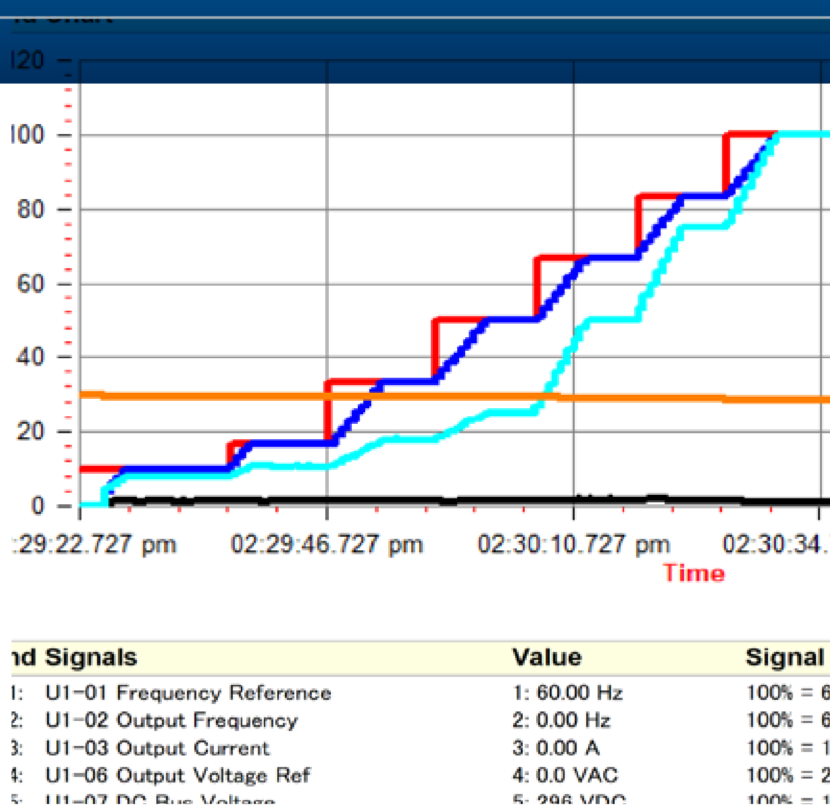
AUTO-TUNING AND VARIABLE FREQUENCY DRIVES

GETTING YOUR MONEY'S WORTH



This document details the importance of performing an auto-tune for your variable frequency drive to ensure efficient operation .

An auto-tune helps the VFD control the motor with specific motor settings

A VFD that is properly auto-tuned will be more efficient with better performance.

INTRODUCTION

Variable Frequency Drives (VFDs) make applications all over the world work better, more efficiently, and with their keypad displays, make the equipment easier to interact with.

Almost to a tee, manufacturers of these wonderful devices recommend that you perform something called an Auto-tune. Why is that? What is that? It isn't anything scary or complicated; it just helps the VFD control the motor with specific motor settings.

Just like the automotive companies not knowing where to put the adjustable seats in your brand new car, the VFD manufacturer can't guess the best default settings for motor information, so they just use some industry standard.

An example might be that the manufacturer of a 40HP, 480volt drive might default their motor full load amp setting per NEC table 430.250 and set it at 52amps from the factory. That would probably not match your new premium efficiency motor. Setting the amps correctly is just the start to getting proper performance.

Performing an auto-tune is easy, so let's discuss the whats and whys of auto-tuning for VFDs.

DIFFERENT THAN SERVO TUNING

Just to be clear, there are other auto-tuning functions out there in the world. As the name auto-tune implies, any operation that will calculate and adjust things automatically at the user's behest, can be called an auto-tune function.

In the world of servo motors and amplifiers, close cousins of the VFD and induction motor, the auto-tuning function will probably have more to do with tuning the servo pair to their loads. The tuning will help adjust gains for positioning and speed loops.

The VFD auto-tuning asks specifically that the load is totally detached from the motor when the auto-tune is performed.

The simple reason for the difference is that servo motors and their amplifiers are always bought together from a single manufacturer. A simple motor code is all that the amplifier needs to know everything about the motor that is attached to it. Conversely, the VFD and motor are only sometimes manufactured by a common company. It is more the norm that brand A motor will probably be used with brand B VFD. Because of this unfamiliarity between the motor and the VFD that auto-tuning becomes the bridge by which good motor information can be passed to the drive.

MONEY'S WORTH

Time really is money. Any time that you "spend" on improving your VFD performance better be worth the time invested. So what is it that a good auto-tune gets you?

If done correctly, a properly auto-tuned VFD will be more efficient (lower current for the same torque) with better performance (more linear and stable operation).

Just by giving the VFD the actual electrical specifications from the motor nameplate, the VFD will not have to assume generic values and produce excess motor flux and possibly even saturate the motor's magnetic field, which won't produce more motor torque but probably will produce more motor losses (heat).

The flipside of the equation is how much time does it take to perform an auto-tune? If you have a nice picture of the motor's specs, say from the motor nameplate, it will probably take around 90 seconds to enter the information and an additional minute to run the auto-tuning. Of course, these are estimates but we are definitely in the neighborhood.

When the auto-tune function is initiated on the keypad, the user enters typical motor nameplate information

HOW IT'S DONE AND WHAT GETS CHANGED

Not every manufacturer does auto-tuning the same but there are probably some common adjustments they all make. Now it would be a mistake to assume that the VFD is doing all of the work. The person that performs the auto-tune routine definitely does their part too. When the Auto-tune function is initiated on the keypad the drive user needs to enter typical motor nameplate information. There isn't really a need to measure or calculate the full load amps if the user can just enter it.

Entering FLA on the keypad

Some specs like slip frequency and leakage inductance are only alluded to on the nameplate and are best calculated by the drive. Once the user enters the relevant motor information, the user is prompted by the drive to start the Auto-tuning process, during which the drive runs and tests the motor to calculate motor specifications not readily found on the nameplate.

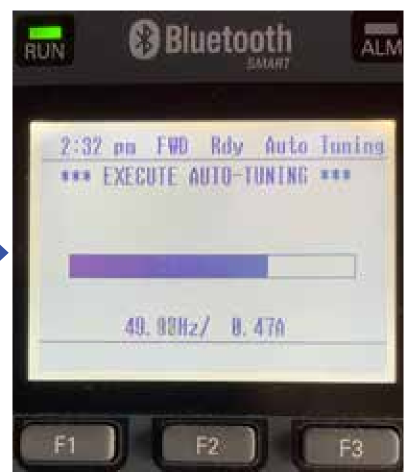
Adjusted Parameters

After the Auto-tune completes, most VFD makers will allow the user to view a list of modified parameters so it can be simple to do a "before and after" check of that list to see what was entered and what was measured or calculated. Typically items that are adjusted are:

- Line to Line Resistance
- Motor rated current
- Motor no-load current
- Motor rated slip
- Energy Savings Coefficient
- Leakage Inductance
- Saturation Compensation
- Motor Iron Loss
- Motor Rated Power

Some specs are best calculated by the drive during auto-tuning

Prompt to start Auto Tune process



Auto tune in process

A single-phase induction motor circuit model is generated to help the drive anticipate and compensate for changing loads on the motor

Some of the measured values are utilized to populate a single phase induction motor circuit model as shown in Figure 1.

All three phases should be the same. For instance, by applying a DC voltage to the stator and measuring the created current with DC current transformers, the drive calculates the Line to Line Resistance which would be R_S in the model.

The rest of the model can be calculated using other techniques and measurements and then extrapolated into three phases. This can help the drive better anticipate and compensate for changing loads on the motor and lead to more efficient regulation of motor operation.

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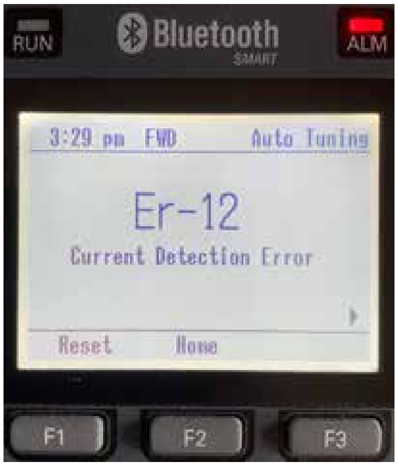
WHEN THINGS GO WRONG

Just like any operation of a VFD and motor, there can be pitfalls that can trip up the auto-tuning. Manufacturers have a separate list of faults that can occur during an auto-tuning routine. The most typical error happens before the auto-tune even begins. Any values input during the auto-tune are checked against the values allowed for the size of drive being auto-tuned and against each other. If the entered full load amps are 100amps but the entered motor size is 40 HP the drive will immediately throw a fault to stop the routine. Even if the horsepower and FLA are reasonable, but exceed the rating of the drive, the drive will stop the auto-tune and display an error code regarding a data entry error.



Typical auto-tuning fault

Because of the fact that a VFD's auto-tuning routine is to probe the motor not the load, most auto-tunes that require rotating the motor to make measurements will also require that the motor and load are disconnected during the auto-tune. The VFD can tell by the amps drawn during rotation whether the load has truly been detached and may fault with a Load Fault rather and complete and accept the auto-tuning adjustments. This leads to another topic, the types of auto-tunes.

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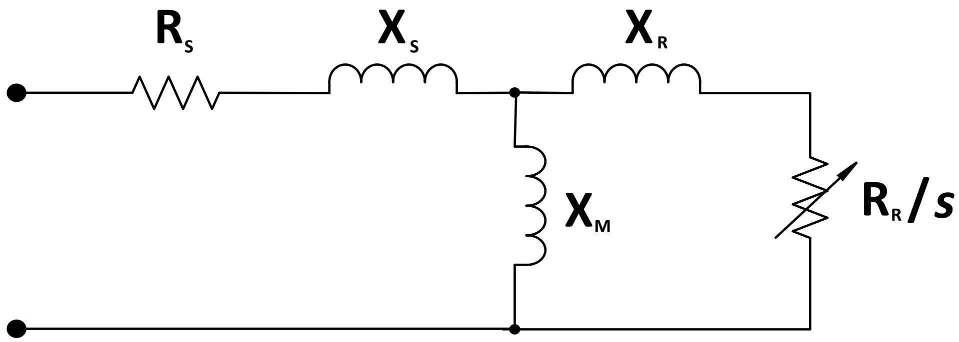

Figure 1: Single-phase induction motor circuit model

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Auto-tune types:

- Uncoupled rotational auto-tune
- Stationary auto-tune

If it is feasible, always insist on the uncoupled rotational auto-tune.

AUTO-TUNE TYPES FOR VFDS

The most effective version of an auto-tuning routine for VFDs and motors requires the motor shaft to be rotated while unloaded. This is know as an **Uncoupled Rotational Auto-Tune**.

There just isn't any replacement for actual measurements that can be made while the motor is actually turning its own shaft.

However, not all applications of VFDs and motors allow for easy uncoupling. Using some sophisticated calculations, some of the motor model information can be estimated using an auto-tune method that does not require motor shaft rotation. These non-rotational auto-tunes are sometimes referred to a **Stationary Auto-tuning**.

Finally, there are some auto-tunes that are very basic and require little information to be entered and take only a few seconds.

For the most part, the auto-tune will just measure the resistance that is inherent in the windings of the stator and the motor cable., basically the line to line resistance mentioned earlier. The advantage of such a simple auto-tune is that the VFD can then compensate for the reduced magnetic field strength due to voltage loss.

We won't cover it here but there are also auto-tuning routines specifically for permanent magnet motors in many of the same VFDs. Some of what the PM auto-tuning routines do is common with what is done with induction motors.

However, even more specific information necessary for a proper auto-tune of a PM motor and wider variety of characteristics are measured as well.

AUTO-TUNING TIPS

Most auto-tuning with VFDs is pretty straightforward and nothing that requires a PhD in electrical engineering. However, there are a couple of things that may make things come out for the best.

First, some motor characteristics, specifically, resistances, will change as the temperature of the copper windings increases. In other words, a hot motor will measure differently than a cold motor. Since during most normal operation the motor will be warm to hot, we would like our auto-tune to reflect that state.

So the tip is to either run the auto-tune multiple times or just run the motor for a while, even unloaded, before performing your rotational auto-tune.

Second, because it is simpler to do a stationary auto-tune, it is tempting to settle for the stationary auto-tune. That would be convenient but a mistake.

Always insist on the uncoupled rotational auto-tune. Often the auto-tune can be run before the application is fully assembled, like on the build floor.

Sometimes it is easier to do the full rotational auto-tune when the motor are only 20ft apart and have a relatively short motor cable.

Later when the application is fully assembled and the motor is 75ft away from the drive and already coupled to the load, a simple Line-to-Line resistance can be run.

This non-rotational resistance tune will not affect the motor measurements but will re-test and update the increased resistance due to a longer motor cable. Viewing the modified VFD settings can confirm the new resistance measurement.

It also may be helpful to do some pre-tune and post-tune measurements. Try using the VFD's built in monitoring displays to complete a table with pre and post monitor values (see Table 1)

If auto-tuning successfully adjusted the VFD from factory default settings, then all of the values in the post-tune will be lower than the pre-tune, with the exception of the DC bus voltage, which at steady state will mostly stay constant.

Another way to compare pre- and post-tuning performance is through free trending software offered by many manufacturers with their Drive Tools Software. (see Figure 2)

These baselines help with seeing any differences in performance and can be a benchmark for future comparisons.

Pre- and post-tune measurements are a good way to validate the effectiveness of your auto-tune

Frequency (Hz) Monitor	Output Current Monitor	Output Voltage Monitor	DC Bus Voltage Monitor
6	Amps	Vac	Vdc
10	Amps	Vac	Vdc
20	Amps	Vac	Vdc
30	Amps	Vac	Vdc
40	Amps	Vac	Vdc
50	Amps	Vac	Vdc
60	Amps	Vac	Vdc

Table 1: Typical data to collect for pre- and post auto-tune monitoring

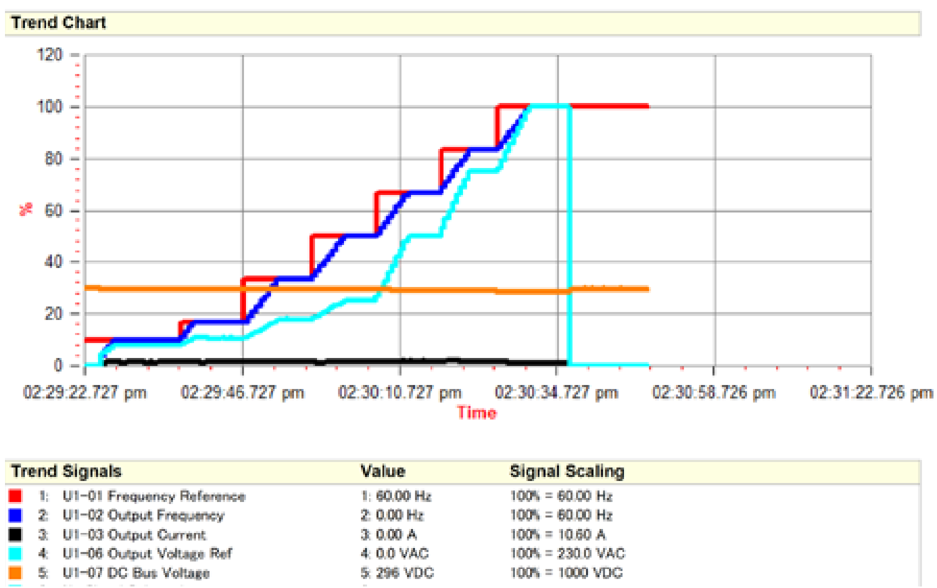

Figure 2: Many manufacturers offer free trending software to compare pre- and post tuning performance

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Auto-tuning VFDs is a quick and easy procedure and well worth the effort.

WORTH THE TIME AND MONEY

The point of this article is to promote auto-tunings as a best practice when it comes to getting the most from your variable frequency drives.

The investment is usually a few minutes of time and the differences can be well worth the effort. The better and more accurate the motor model that the VFD has, the better and more efficient the motor control will be.

Of course you can get close to the same results by hand calculating the leakage induction. Wouldn't that be a fun exercise?

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Yaskawa is the leading global manufacturer of low and medium voltage variable frequency drives, servo systems, machine controllers and industrial robots. Our standard products, as well as tailor-made solutions, are well known and have a high reputation for outstanding quality and reliability.

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