



VACON® 100 Commissioning with Synchronous Reluctance Motors



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1 Introduction

1.1 Purpose of this Guide

This guide provides information for the commissioning of VACON® 100 drives that operate synchronous reluctance motors (SynRM). The guide is intended for use by qualified personnel. To use the drive safely and professionally, read and follow the instructions. Pay particular attention to the safety instructions. Always keep this guide available with the product.

1.2 Safety

Read the information included in this guide carefully.

This guide is intended to be read with the operating guide and application guide of the product. The safety information in these guides also applies.

NOTICE

Information in this guide is intended as appending information to the product guides.

- Pay particular caution when applying the information in this guide into use.

1.3 Synchronous Reluctance Motors and Tuning of Open-loop Control

SynRM is a synchronous motor with a similar stator structure as used in induction and permanent magnet motors. The rotor has a laminated structure where high saliency is targeted. Similarly to the induction motor, the magnetic field produced by the stator current magnetizes the rotor of the SynRM. The rotor does not include any current conducting bars and therefore no conduction losses in the rotor are produced and rotation is synchronous with the stator magnetic field. Without current in the stator, the motor does not produce back-EMF voltage to the stator terminals when the shaft is rotated.

U/f-curve operation (open-loop control) with SynRM is basically the same as with induction motors: U/f-curve voltage setting defines the reactive power of the motor, while motor load torque defines the real power. Load torque also affects the reactive power.

U/f control is a robust control method, but if *P3.1.2.12 Energy Optimization* is not turned on, it does not use the full energy efficiency capability of the SynRM. More information about energy optimization is provided in [3.3 Energy Optimization Function](#) and in the application guides.

2 Commissioning

2.1 Commissioning U/f-control for SynRM

To drive the SynRM with U/f-control is a matter of setting the motor nominal values and U/f-curve settings correctly. These parameters can be set with two methods:

- Automatic tuning of the U/f-curve
- Manual tuning of the U/f-curve

Both of these methods are addressed in the following sections.

Before advancing to the tuning of the U/f-curve, find the values for the following motor parameters:

- Motor nominal voltage
- Motor nominal frequency
- Motor nominal speed
- Motor nominal current
- Motor power factor, same as $\cos \phi$
- Motor nominal power

Some motor manufactures give the motor nominal voltage in no-load operating point and some give it in full-load operating point. Use the voltage in the full load operating point for the motor nominal voltage. If there is no extra information given about the motor nominal voltage, then use it as it is.

Motor nameplates of SynRM often lack the information of power factor ($\cos \phi$). If this information is not provided, use the value 0.70.

Fully automatic tuning of the U/f-curve is feasible only if the motor can be run without a load. If the motor nominal voltage is lower than the rated voltage of the drive, the drive uses a higher field weakening point frequency to allow high speeds to be driven with the correct U/f ratio. If running the motor without a load is impossible during identification, then identification at standstill can be used. If performing identification at standstill, the drive calculates the field weakening point and voltage automatically from the motor nominal values. In addition to setting the field weakening point, both automatic identification methods also adjust the low frequency range of the U/f curve.

2.2 Automatic Tuning of the U/f-curve

If the motor identification is performed, the U/f curve is automatically configured. Before tuning the U/f-curve, select the *P3.1.2.3 Switching Frequency*. To perform the identification run, follow these instructions.



NOTE:

The motor starts to rotate during this action. To get the best possible result, let the motor run without any load. After the identification run, the drive sets the U/f-curve to the correct settings and the motor is ready to run.

1. Set the motor nominal values.
 - a. Set the value for *P3.1.1.1 Motor Nominal Voltage*.
 - b. Set the value for *P3.1.1.2 Motor Nominal Frequency*.
 - c. Set the value for *P3.1.1.3 Motor Nominal Speed*.
 - d. Set the value for *P3.1.1.4 Motor Nominal Current*.
 - e. Set the value for *P3.1.1.5 Motor Cos Phi*.
 - f. Set the value for *P3.1.1.6 Motor Nominal Power*.
2. Set the value for *P3.3.1.2 Maximum Frequency Reference*.

The maximum rotation speed of the motor can be given in the motor nameplate. Set the maximum frequency reference so that the maximum speed is not exceeded.

The motor is accelerated to 67% of the nominal value during the identification run. If the maximum frequency reference is below this value, the identification run does not complete successfully, and reports a failure.

3. Set the value of *P3.1.2.2 Motor Type* to 2 (*Reluctance motor*).
4. Set the value of *P3.1.2.4 Identification* to 2 (*With rotation*).
5. To start the identification run, press the START button within 20 s from the previous step.

If the identification run is successful, the motor current, voltage, and speed behave as shown in [Figure 1](#), but the absolute values of the variables change with different motors.

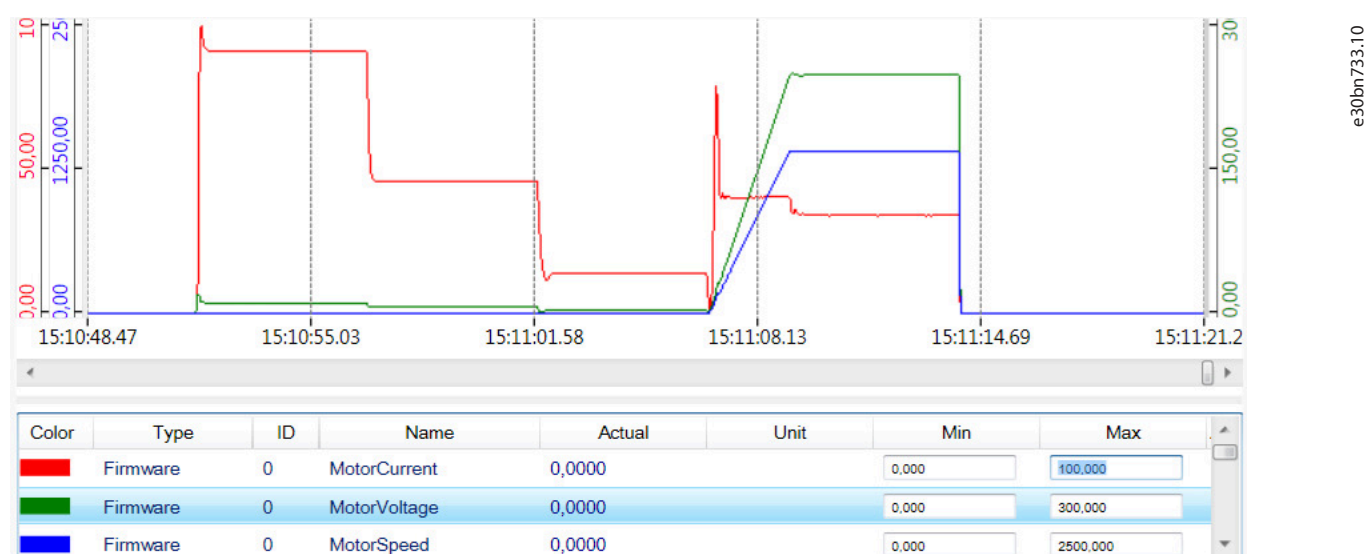


Figure 1: Motor Current, Voltage, and Speed During a Successful Identification Run with Rotation Shown in VACON® Live PC Tool

NOTE: If identification at standstill was performed (*P3.1.2.4 = 1*), the identification run does not rotate the motor. The field weakening point is calculated from the motor nameplate values in this case.

NOTE: If the motor nameplate values are changed, it is recommended to perform the identification run again.

2.3 Manual Tuning of the U/f-curve

The U/f curve of the SynRM is defined by 3 points in the U/f-plane. The 3 points are zero, middle point, and field weakening point frequencies (see [Figure 2](#)). In the manual setting of the U/f curve, the voltages and frequencies in these 3 points are determined by running the motor without load and adjusting the voltage so that the wanted current without load is obtained. If rotation without load is impossible, tune the U/f curve to obtain the desired current (instructions for this case are not included here).

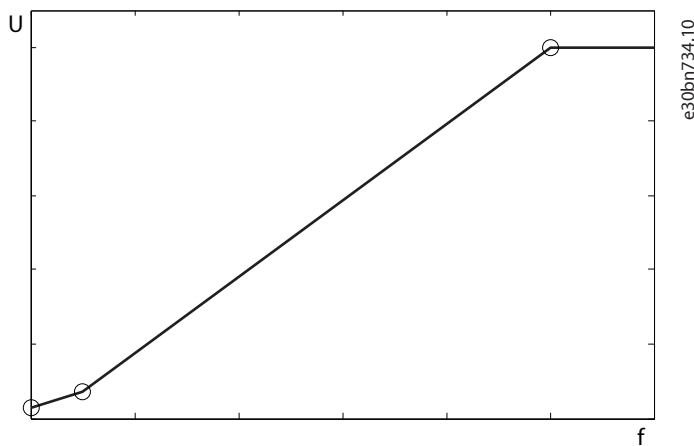


Figure 2: Example of the U/f Curve

Before manually tuning the U/f-curve, select the *P3.1.2.3 Switching Frequency*. To set the U/f curve, follow these instructions. This method is only valid for an unloaded motor.

1. Set the motor nominal values.
 - a. Set the value for *P3.1.1.1 Motor Nominal Voltage*.
 - b. Set the value for *P3.1.1.2 Motor Nominal Frequency*.
 - c. Set the value for *P3.1.1.3 Motor Nominal Speed*.
 - d. Set the value for *P3.1.1.4 Motor Nominal Current*.
 - e. Set the value for *P3.1.1.5 Motor Cos Phi*.
 - f. Set the value for *P3.1.1.6 Motor Nominal Power*.
2. Set the value for *P3.3.1.2 Maximum Frequency Reference*.

The maximum rotation speed of the motor can be given in the motor nameplate. Set the maximum frequency reference so that the maximum speed is not exceeded.

3. Set the value of *P3.1.2.2 Motor Type* to 2 (*Reluctance motor*).
4. The drive automatically sets the values for *P3.1.4.2 Field Weakening Point Frequency* and *P3.1.4.3 Voltage at Field Weakening Point*. If necessary, reconfigure the values.
5. Set the value of *P3.1.4.1 U/f Ratio* to 2 (*Programmable*).

The middle point of the U/f curve is enabled with this selection.

6. Set the value of *P3.1.4.6 Zero Frequency Voltage* to a low value (0–1.00%).
7. Start the drive with a zero frequency reference while monitoring the *V2.3.4 Motor Current*.
8. Decrease/increase the zero frequency voltage until the motor current is 40–60% of *P3.1.1.4 Motor Nominal Current*.
9. Set the value for *P3.1.4.4 U/f Midpoint Frequency* as percentage of the motor nominal frequency, equal to *P3.1.4.6 Zero Frequency Voltage* as:

$$f_{\text{midpoint}} = \frac{f_{\text{zerofreq\%}}}{100} \times f_{\text{nom}}$$

For example, if the zero frequency voltage is 7%, then the midpoint frequency should be 3.5 Hz with 50 Hz motor nominal frequency.

10. As a first guess, set the value for *P3.1.4.5 U/f Midpoint Voltage* to 1.4 x the value of *P3.1.4.6 Zero Frequency Voltage*.

11. Start the drive without the load and increase the frequency reference while monitoring the motor current.
 - a. If the motor current deviates too much from the zero frequency current (same current as in step 8) at low speeds (<30% of nominal speed), decrease/increase the value of *P3.1.4.5 U/f Midpoint Voltage*.
 - b. If the motor current deviates too much from the zero frequency current (same current as in step 9) at higher speeds (>60% of nominal speed), decrease/increase the value of *P3.1.4.3 Voltage at Field Weakening Point*.
 - c. Iterate through the steps a and b until the current stays fairly constant at all frequencies below the field weakening point frequency.

In steps 8, 11.a, and 11.b, the motor current behaves like presented in [Figure 3](#).

- If the voltage is much too low, the current is too high (over 50% of the motor nominal current).
- If the voltage is slightly too low, the current is at a minimum (less than 30% of the motor nominal current).
- If the voltage is correct, the current is approximately 50% of the nominal current.
- If the voltage is too high, the current is too high.

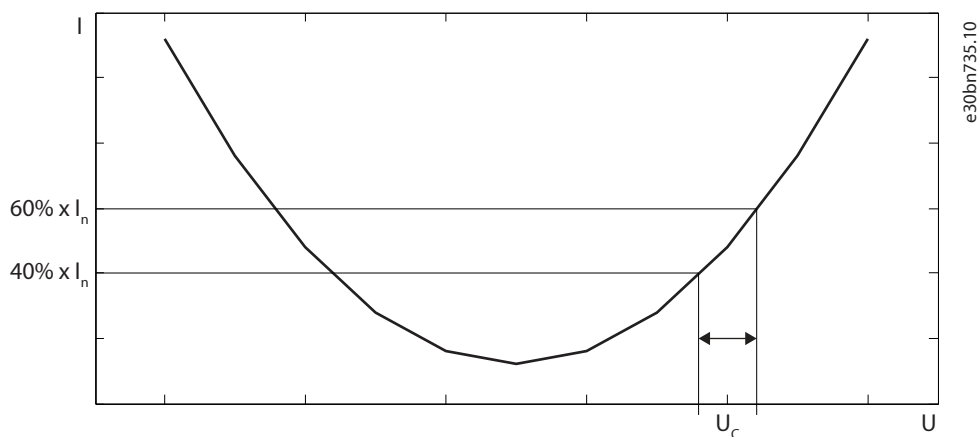


Figure 3: Relation of Voltage and Current at a Certain Operating Frequency

I_n	Nominal current		
		U_c	Correct voltage

3 Additional Settings and Troubleshooting

3.1 Starting of SynRM

If the motor does not start rotating, perform one or multiple of the following actions.

1. Increase the ramp time with *P3.4.1.2 Acceleration Time 1*.
2. Adjust the shape of the ramp to resemble an S-curve with *P3.4.1.1 Ramp 1 Shape*.
3. If a high starting torque is needed, activate *P3.1.4.9 Auto Torque Boost* by setting it to 1 (Enabled).

The automatic torque boost increases the available torque in low frequencies during start up. Best performance is obtained if the stator resistance is identified by performing the identification run with *P3.1.2.4 Identification*. Identification at standstill is enough.

4. In high inertia demanding applications (fans, for example), parking of the rotor can be required. In these cases, check the parameters affecting magnetizing time: *P3.4.3.1 Start Magnetizing Current* and *P3.4.3.2 Start Magnetizing Time*.
5. If current/torque are not steady during the acceleration of the motor, tune *P3.1.4.13.1 Torque Stabilator Gain* while observing the behavior of the drive.

3.2 Starting a Rotating Motor

If starting of a rotating motor is needed, enable the Flying Start function.

1. To enable the Flying Start function, set *P3.2.4 Start Function* to 1 (Flying start).

The ramping of the motor speed towards the frequency reference is started approximately 2 s after the START button is pressed.

3.3 Energy Optimization Function

The Energy Optimization function *P3.1.2.12* is an optimization algorithm that automatically adjusts motor voltage and searches the most efficient operating point. The function raises the energy efficiency of both the motor and the drive by finding the minimum current that produces the required load torque.

The amplitude of magnetic flux in the machine determines the amplitude of the EMF voltage produced by the SynRM. The flux can be adjusted by changing the stator voltage at a given frequency. The amount of flux also affects the amount of torque produced by the machine. The higher the amplitude of the flux, the lower current is needed to produce a certain torque. On the other hand, current is also needed to produce the flux itself. Therefore an optimal point can be found where the total current (vector sum of the flux and torque producing current components) gets its minimum value with a certain load torque. This point is called the maximum torque per ampere (MTPA) operating point.

With correct setting of the U/f curve the MTPA point can be found for a high load torque. The efficiency optimization function searches the MTPA point also for partial load and overload conditions.



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