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INVERTER TIP: Soft-start and V/f technique

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In modern industry, one of the most usual devices are three-phase asynchronous AC induction motors, which can be found in a wide range of applications such as liquid pumps, fans, compressors, industrial conveyor belts, traction systems, and other electromechanical system used to move anything.

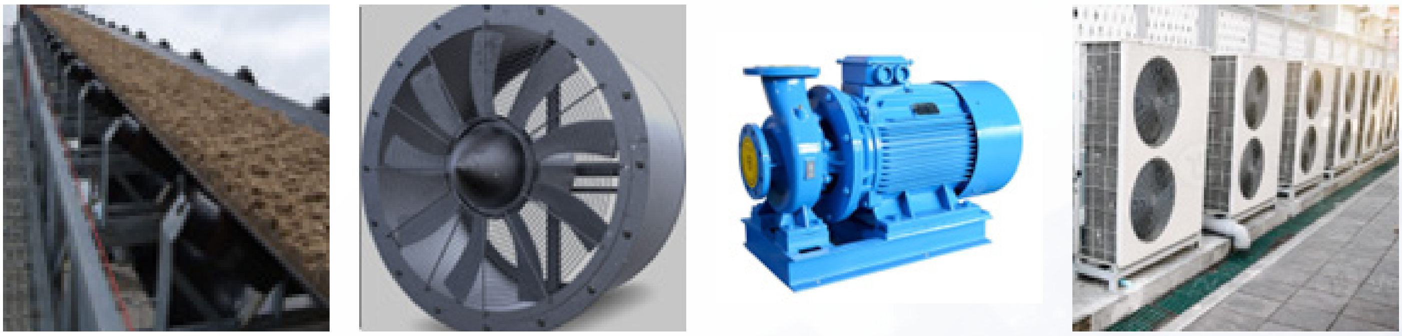

Fig 1.- Typical applications of three phase induction motors

There are several types of asynchronous motors, but the most usual is the squirrel cage induction, due to its simplicity, ruggedness, efficiency, cheapness and low maintenance. In addition, depending on how they are built, it is possible to choose motors with different specifications like speed rotation, stability of the speed with torque, the curve of torque, nominal voltage and frequency, number of phases of the mains, current with a locked rotor, etc…

In low load applications (< 1 HP) and low initial torque of the load, it is possible to use single phase motors, but there is a need of systems like auxiliary inductors with big external capacitors and/or centrifugal switches to facilitate the start-up, which require certain maintenance over time. This type of motor does not work properly with inverters with V/f start-up techniques. For applications with high initial torque or more than 1 HP, it is highly recommended to use three-phase motors.

The main issue when using an induction asynchronous motor is the inrush current in the start-up. This current is named by the manufacturers as locked rotor current (LRA) and can go from 5 to 12 times the nominal current of the motor for some hundreds of milliseconds, depending on the inertia of the load.

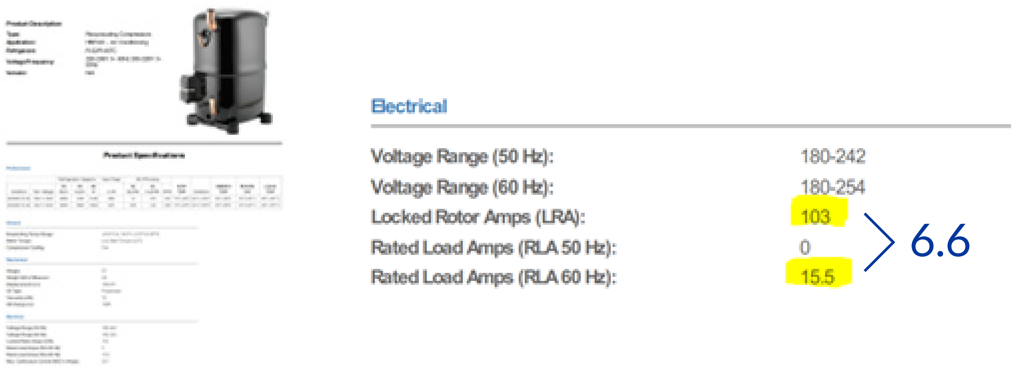

Fig 1.- Typical applications of three phase induction motors

This factor depends on the construction parameters of the motor as the number of poles, shape of the rotor bars, gaps, etc..

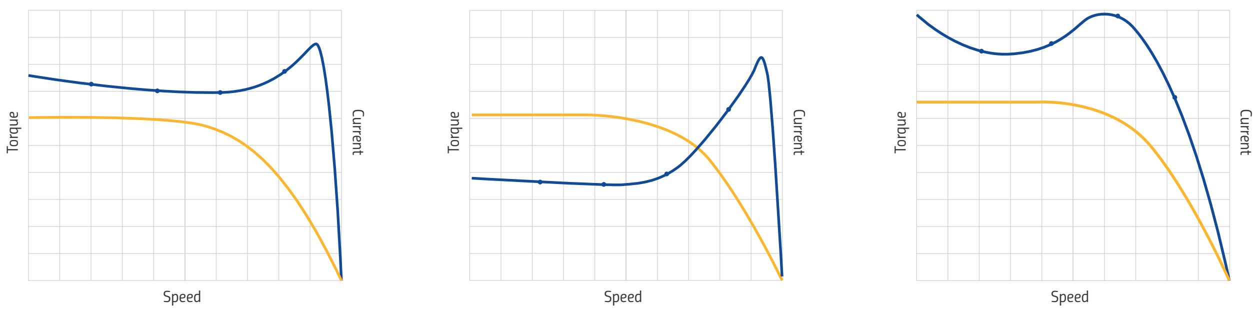

Fig.3.- Example of three types of motors with different curves of torque (blue) and current (yellow) vs. the rotation speed (which is proportional to the mains frequency)

The input power system is very stressed when providing peak current in direct connection, and it also has significant disadvantages:

1. Mechanical and thermal stress on the stator motor windings reduces its life
2. Voltage dip in the electrical power system due to the high inrush current, which affects other devices connected to the same lines
3. If the current of the mains is enough, an unnecessarily high starting torque, increased mechanical stress on the rotor, bearings, gearbox, couplings and the final load

To reduce the inrush current there are 4 mainly methods:

1. Star-delta connection
2. Startup with stator resistor
3. Electronic soft-start starters
4. Inverters with V/f startup strategies

The Star-Delta connection is the most commonly used in the industry (Fig. 3). It reduces the voltage in the windings to 57.7 % of the line-line voltage. Hence, with the reduced voltage, the starting current and the torque decrease by a factor of 1/3.

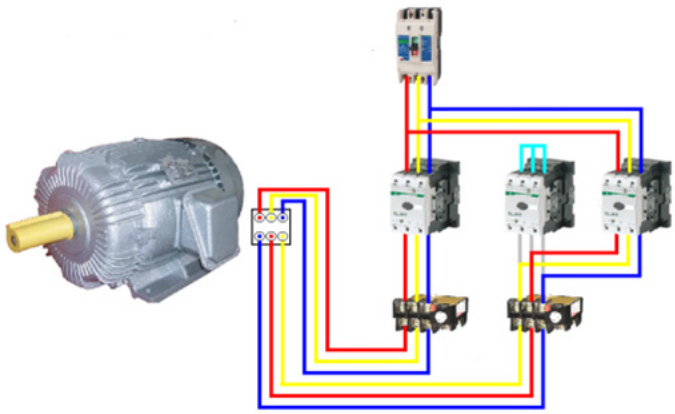

Fig 3.- Star-Delta wiring

This system needs a large contactor to switch between operation modes. The method of the stator resistors works similarly to the star-delta connection, but with additional high power resistors and contactors.

In systems fed from a battery or critical applications that must work in case of mains failure, it is necessary to use **inverters** working from a DC bus, and provide an AC three-phase voltage and frequency adjusted to the load. If the load is an asynchronous induction motor, the large inrush current during the start-up should be controlled to protect the battery, other loads on the DC BUS, the BMS and other protections.

The typical chart of an induction asynchronous motor (Fig.5) shows the behaviour of the current and torque vs the rotation speed. The synchronous rotation speed Ns is proportional to the mains frequency (NS = k * f). The slip speed is the difference between the electrical synchronous rotation speed and the real mechanical speed of the rotor S=(Ns-N)/Ns

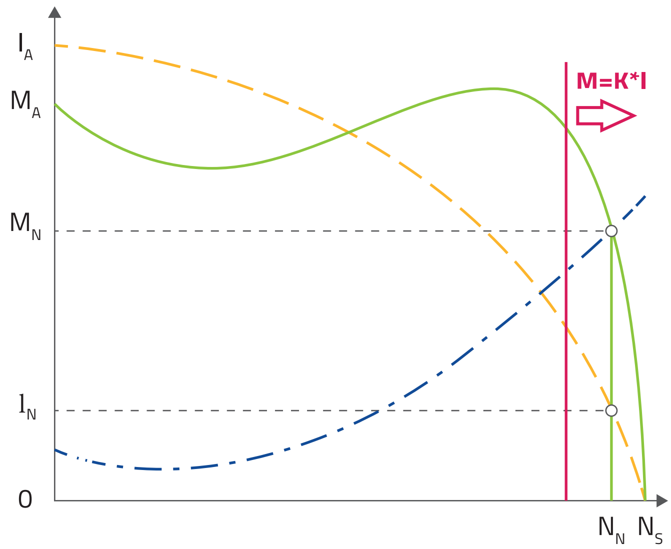

Fig. 5.- Green: motor torque, blue: load torque and yellow: motor current.

When the motor is stopped, the initial current IA and the torque at 0 rpm is MA. Both parameters are higher than the nominal IN and MN, and there is no linear relationship between them when the motor works to the left of the red line (for mains frequency <= that the nominal motor design frequency)

The motor will work best with a little slip speed(mechanical speed near the electrical speed) so then the torque is proportional to the current (right of the red line).

This way, a constant flux will be mantained with a small Ns-N and therefore a constant current, changing properly the Voltage/frequency dynamically during the motor startup ramp.

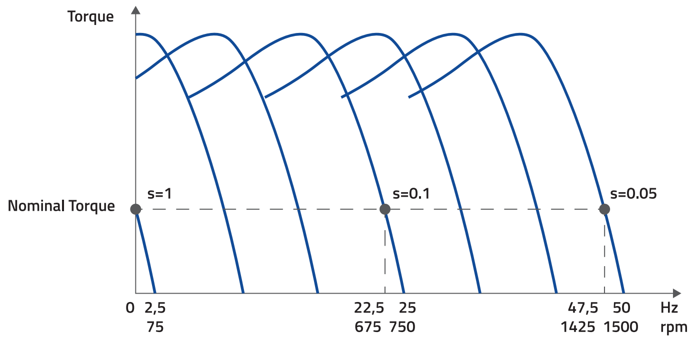

Fig. 6 .- Chart of Torque-RPM vs V/f variation at constant flux.

The benefits of this method working with DC/AC inverters are:

- Motor startup current in the same range as the nominal current
- No mechanical stress on the motor and the load
- Electrical protections ranged to the nominal values
- No overcurrent stresses on the inverter semiconductor
- No extra peak power on the DC input, battery and BMS
- No use of contactors and/or power resistors
- Reduce the cost of the components and wiring of the setup
- Increase the reliability of the system (there are no electromechanical components)

All Premium PSU´s three-phase inverters (**ODX-1300, ODX-3000, ODX-4500, ODX-6000, and OVX-6400**) have the possibility of setting a voltage ramp at constant frequency and V/f ramp during the startup. It is possible to configure the nominal voltage and frequency (Vo and Fo), the initial frequency (Fi), and the ramp-up time, ramp down time, and minimum output voltage (Vm), to adjust to the customer's application (Fig. 7).

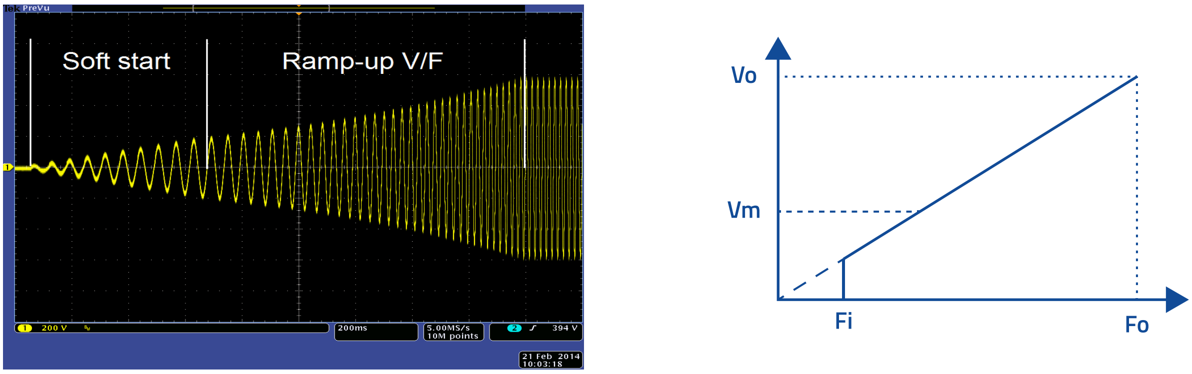

Fig 7.- Start up from Fi= 16 Hz to Fo=50 Hz

Also, Premium PSU´s inverters have analog control inputs to manage the output enable, the rotation direction, or a programable secondary speed for the motor (for example to provide 2 set points in an HVAC compressor Fig 8). In fact, it is highly recommended to use these inputs to manage the output and it does not connect the motor to the inverter by a contactor with the output enabled.

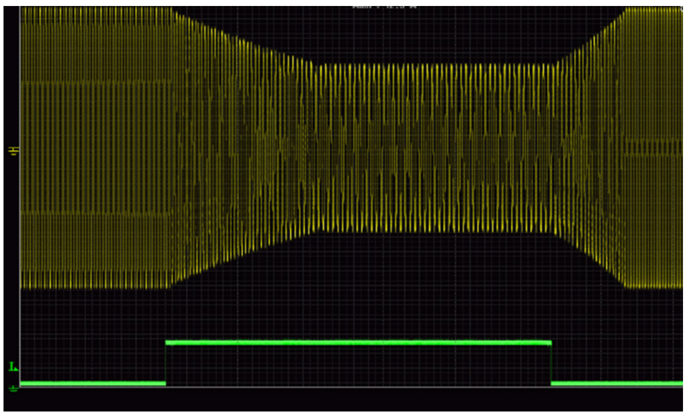

Fig 8.- Changing the output by the input signal from 50 Hz / 400 Vac (nominal power) to 30 Hz / 240 Vac (low power). Yellow: output voltage and Green: Mid-Power input signal

Configuration and management of the output can be done by communication ports (RS-232 and/or CAN). It is important to emphasize that all Premium PSU´s inverters have **TRUE sinus output and very low distortion wave** (THD < 4%). This specification is very important for motor applications due to the high switching frequency currents are minimized, therefore the losses in the motor cage and windings are not increased. Also, bearings are not affected by HF common mode currents.

ABOUT PREMIUM PSU

Premium PSU is one of the largest power supply companies in Europe, offering solutions to the industrial market in high-tech machinery, transportation, energy, or extreme environment applications. Founded in 1981, Premium PSU designs and manufactures power conversion systems for customers all around the world.

Premium PSU's power conversion system range includes DC/DC converters, uninterrupted power supplies, DC/AC inverters, AC/DC power supplies and any solution that requires high reliability from 50W to 60kW.

All products comply with the specifications and regulations that each application requires and all projects, from the concept and design until the homologation of the product, are carried out in Barcelona under strict quality controls.

Custom is Premium PSU's standard, so any current product variation or new development can be done by our R&D department, a team of over 50 engineers with wide know-how.

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