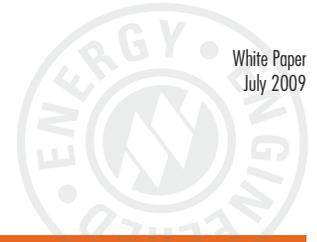


# AC Variable Frequency Drive with Static Stepless Simulation Software Outperforms Traditional Static Stepless Crane Control



Aaron Kureck  
Controls Product and  
Development Manager

Material Handling

Until the advent of the latest generation of Variable Frequency Crane Controls, AC Static-Stepless control was the control of choice for the most demanding crane applications where complete speed and torque control were critical to performance. They include Portal/Whirly and Quay Cranes, Wood Yard Cranes, Turbine Room and Reactor Room Cranes, Scrap Yard and Refuse Cranes, Machine Shop Cranes and Mill Duty Cranes of every sort. This paper will discuss how the Variable Frequency Drive with crane specific software has revolutionized AC Crane Control and made AC Static Stepless Control virtually obsolete, in particular for cab operated cranes with foot brakes.

## AC STATIC STEPLESS – THE FORERUNNER OF MODERN CRANE CONTROL

AC Static Stepless controls use wound-rotor motors, solid state components, and stepless induction master switches to provide infinitely variable-speed and torque control. Creep-speeds of 10:1 are possible. It is called “stepless” because it varies the motor speed by changing the inductance of a wound rotor without the use of speed step magnetic contactors and resistors. The rate that the crane accelerates or decelerates is completely under the operator’s control – only limited by available torque and how quickly the operator advances the master switch. Plugging control is integral on most traverse systems.

However, performance notwithstanding, AC Static Stepless Controls are not without their problems. These controls are very expensive. They use a multitude of components such as saturable reactors, transformers, and/or thyristors. The poor output waveform and fixed secondary resistor result in poor efficiency at reduced speed, which may produce excessive motor heating, especially during prolonged low speed operation. Bridge and trolley systems have a tendency to accelerate to full speed when lightly loaded and accurate speed regulation can be problematic. Systems with saturable reactors require a large amount of space and add considerable weight to a crane.

## VARIABLE FREQUENCY CRANE CONTROL—THE NEW STATIC CONTROL

There has been perhaps no other technological development in the past 25 years that has done more to revolutionize AC crane controls than the Variable Frequency Drive (VFD). The technology offers the crane user several benefits over traditional types of AC motor control systems. Although VFDs are often used with existing wound-rotor motors, they are normally used with single-speed squirrel cage induction motors which are easier to obtain, less expensive and require less maintenance than either wound-rotor or multi-speed motors. VFDs provide soft-starts and can accelerate or decelerate to any desired speed through electronics, so wear and tear on the motor and other mechanical and electrical drive components is virtually eliminated or significantly reduced. Speeds are programmable – offering precise placement and positioning of loads. Finally, they reduce the chance for dangerous load swing because the crane changes speed and direction smoothly and accurately.

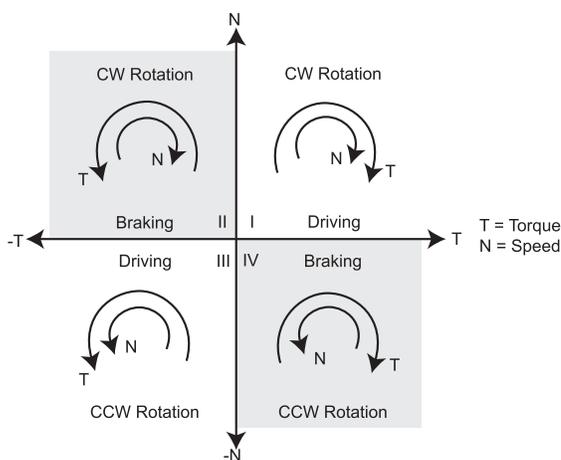
Perhaps the most significant thing about VFDs is that, unlike any technology before them, they address the issue of deceleration and stopping. Gradual and smooth deceleration is possible through dynamic (electronic) braking. This enables a crane or hoist to come to a complete stop before engaging the brake. Electric brakes function simply as holding devices, similar to a parking brake on a car, rather than a stopping device. Consequently, brake wear is virtually eliminated.

With serial communication, VFDs provide reliable digital linkage among various crane system peripherals, including Modbus, Modbus+, Profibus, and Ethernet. Interactive drive software tools further simplify trouble shooting, and allow maximum versatility to upload/download, monitor and save drive parameters.

## FLUX VECTOR – TRUE FOUR-QUADRANT CRANE CONTROL

Working in a closed-loop system, flux vector motor control utilizes an incremental encoder to monitor the speed and direction of the motor shaft. Since the speed and direction of the motor shaft are always known (via the encoder), the Flux Vector Crane Control can calculate the torque demand and adjust both the frequency and voltage accordingly. The drive is capable of controlling torque and speed in four separate speed-torque quadrants.

### Quadrant I – Bridge or Trolley Forward:



### Forward Torque

Motor is rotating clockwise in a positive direction with torque applied in the same direction (driving)

### Quadrant II – Bridge or Trolley Forward: Reverse Torque

Motor is rotating clockwise in a positive direction with torque applied in the opposing direction (braking) i.e. regenerating energy back into the line (reverse-plugging)

### Quadrant III – Bridge or Trolley Reverse: Reverse Torque

Motor is rotating counter-clockwise in a negative direction with torque applied in the same direction (driving)

### Quadrant IV – Bridge or Trolley Reverse: Forward Torque

Motor is rotating counter-clockwise in a negative direction with torque applied in the opposing direction (braking) i.e. regenerating energy back into the line (reverse-plugging)

Torque requirements vary greatly between cranes and crane motions, depending upon the particular type of crane, the job to be done, and/or performance desired. Flux Vector Crane Control, with its built-in digital microprocessor and crane specific software, provides the necessary flexibility in programming to meet the performance criteria of just about any production need.

For example, the Flux Vector Crane Drive can be programmed to provide ramped acceleration and deceleration, which reduces load swing, provides controlled dynamic braking, and permits a less skilled operator to safely control the crane—or—the crane operator can be given more control of speeds, acceleration, deceleration and braking, similar to that used in traditional AC Static Stepless Control.

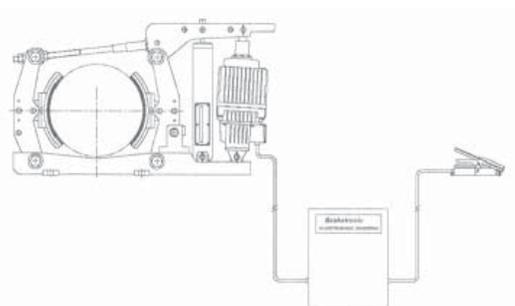
## STATIC STEPLESS SIMULATION SOFTWARE – A UNIQUE CONCEPT IN CRANE CONTROL

A unique concept for controlling a cab operated crane (US Patent 7,190,146) was developed by Magnetek and embedded in the software of its Flux Vector Crane Drive. This feature, called “Static Stepless Simulation,” allows the operator to use a footbrake to either augment or completely control the deceleration and/or stopping of the crane while at the same time provides improved reverse-plugging response, eliminates motor current spikes, and reduces open circuit motor decay.

A skilled overhead crane operator relies on hand-eye coordination, judgment, and this crane’s control and braking means to safely and accurately lift and position heavy loads. Experienced crane operators are known for their skill in placing delicate loads on a dime and controlling load swing to literally catch a load. They frequently plug, i.e. rapidly reverse bridge and trolley motors to develop a counter-torque that slows or even stops a crane. In addition, a drift point is often used on the motion master to release the electric brake, thus permitting the bridge or trolley to coast until retarded by friction or the foot brake. These attributes are difficult to replicate with technology, alone, thus illustrating the need for control options that allow for enhanced man-machine interface.

With traditional AC Static Stepless Control, current and voltage spikes can occur when a reversed polarity voltage is applied (reverse-plugging). These transient spikes can even occur when the operator makes a speed adjustment while coasting in the same direction. With the use of Flux Vector crane control, it is not necessary to reverse the polarity of the motor. Instead, the motor is retarded by the application of an adjustable amount of retarding torque, determined through the drive’s software and the position of the master switch in the direction opposite of the crane’s motion. This helps to insure a smooth transition from coasting to slow-down and even allows reversing the direction of travel of the bridge or trolley.

What is unique with the Static Stepless Simulation software is that the Flux Vector Drive sends a frequency to the motor substantially equal to the frequency at which the coasting motor is rotating thus creating a speed match that reduces spikes and virtually eliminates open motor decay. When a running induction motor is disconnected from its power source, the motor generates residual internal voltage until the stored residual magnetism dissipates due to losses in the iron as the motor loses speed. Response time is thereby improved since no time is lost waiting for the magnetic field to decay in the rotor.



**Braketronic® Controller**

Included with Static Stepless Simulation software is a feature called "Brake Stand Prevention". When an operator applies pressure to the brake foot pedal, a signal is sent to the VFD from either a micro switch or hydraulic pressure switch that braking is applied. The drive software in turn prevents the motor from driving into the brakes thus saving wear and tear on the controls, brakes and crane.

Hydraulic brake systems tend to leak and create maintenance and environmental issues. However, brake-by-wire packages are now available, with foot pedal operated AC Thruster Brakes, that address these issues and provide operators with the same feel they had with hydraulic brakes.

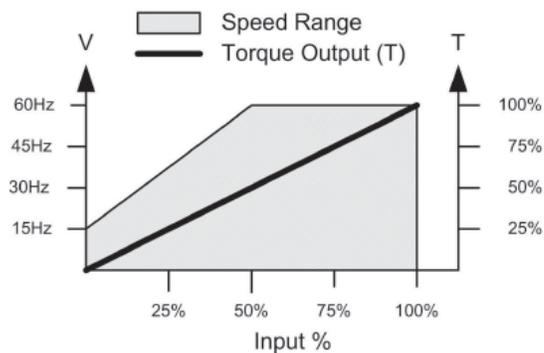
### EXCEPTIONAL SPEED REGULATION – THE HALLMARK OF STEPLESS CONTROL

Exceptional speed regulation has been the hallmark of both traditional AC Static Stepless and AC Flux Vector Crane Controls. Wherever precise spotting or extremely slow speeds are required such as in the Aerospace Industry or Nuclear Power Plants, these controls have been the performance leaders. However, AC Flux

Vector Crane Control routinely provides creep speeds of 1000:1, compared to only 10:1 for AC Static Stepless, and

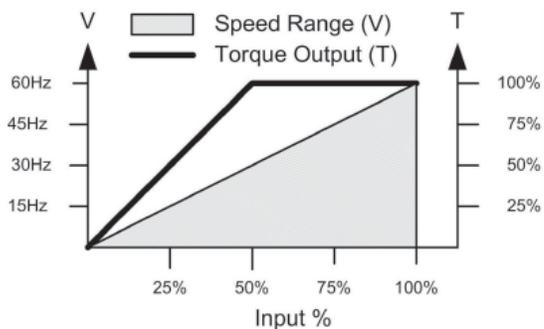
does so without incurring the motor heat-buildup that normally accompanies prolonged slow speed operation.

Flux Vector Crane Control with Static Stepless Simulation software can be programmed to operate in several modes.



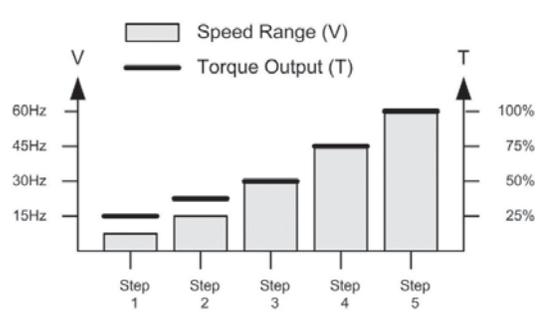
**Figure 1**  
**Stepless - Linear Torque - Slight Speed Limiting**

In this configuration, some speed control at lower input levels, but does not limit the speed at the upper end. Output torque is the same as in traditional AC Static Stepless Control.

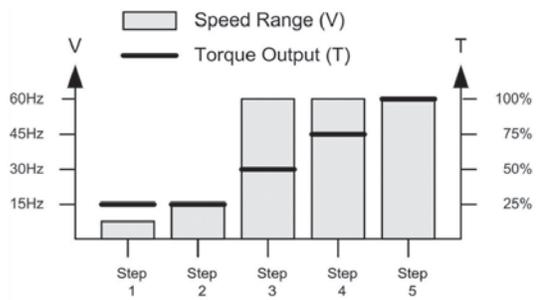


**Figure 2**  
**Stepless - High Torque - Linear Speed**

In this configuration, the output torque is very high, but the output speed will increase at a constant rate as the master switch is moved through its range. Incremental steps can be independently programmed to suit any desired operator preference or performance criteria. Creep speeds are predictable and can be made even more functional when Micro-Positioning is enabled.



**Figure 3**  
**Proportionally Stepped Torque and Speed**  
 In this configuration, the output torque and speed limits increase at a constant rate in discrete steps as the master switch is moved through its range.



**Figure 4**  
**Un-Proportionally Stepped Torque and Speed**  
 In this configuration, at low input levels, the output speed of the drive is very limited. After step two, the drive returns to a typical Static Stepless Simulation type of response. Each incremental step can be independently programmed to suit any desired operator preference or performance criteria.

## CONCLUSION

A Flux Vector Crane Drive with Static Stepless Simulation eliminates current spikes and excess mechanical torque/stress on the drive train; allows quick but smooth starting or changing of direction; reduces maintenance costs; and easily interfaces with existing induction masters, footbrakes and motors.

Static Stepless Simulation provides the best of all worlds, by combining the intellect, judgment, dexterity and other positive human traits of the crane operator with the latest in crane control technology and safety. It is the ideal control for high performance cab controlled overhead cranes.

## MAGNETEK PRODUCTS

Static Stepless Simulation software is designed for IMPULSE®•VG+ Series 3 drives used on traverse motions to provide an effective means to slow or stop the motion of the bridge or trolley.

The Braketronic® Controller utilizes solid-state drive technology to provide variable torque control to industrial shoe and disc brakes. This product enables single or multiple brakes to be proportionally controlled by a foot pedal, master switch, or radio as well as selectively by aforementioned means. This controller may also be configured to gradually apply brakes by pre-programmed ramping, initiated by single-step control devices or pendant stations.