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ACH550 Flux Optimization White Paper

Power and productivity for a better world™

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Executive Summary

This whitepaper discusses the methods used within the ABB ACH550 Variable Frequency Drive (VFD) to control the voltage/frequency output ratio. The variations in V/Hz ratios have an effect on system efficiency that can result in lower energy use.

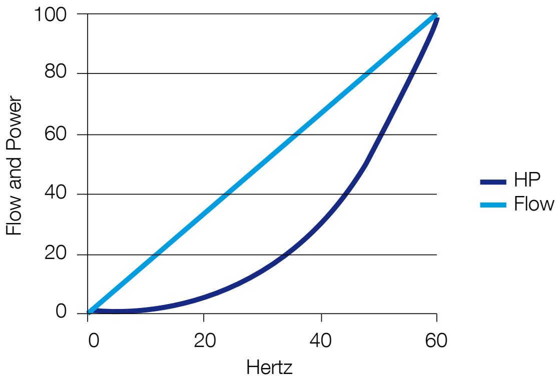
VFDs are used on many types of connected loads. When VFDs are used on systems with variable torque loads, i.e. fans and pumps, there are V/HZ ratios that may be used to improve system efficiency.

Introduction

ABB and other VFD manufactures have utilized various techniques within the software of VFDs to control the Voltage/Hertz ratio on the output. For constant-torque loads typically found in industrial applications, a linear V/Hz ratio is utilized to maintain full torque output from the motor at various motor speeds. However, when VFDs are used on variable-torque applications, a linear V/Hz ratio typically will provide the motor with a higher amount of voltage than is required to control the attached load. This type of load resulted in a V/Hz ratio, where the applied voltage is proportional to the square of the voltage applied to the motor when used on a ABB drive. This method reduces the output voltage to the motor greatly, which results in increased motor efficiency.

ABB has determined that there is additional savings potential in variable-torque loads, if the output voltage is reduced further, when the load is lower than what is expected for a variable-torque load; example: an oversized motor (i.e. a 42 BHP load placed on a 50HP motor). The software calculation that has been implemented in the ACH550 is known as Flux Optimization. This optimization continually monitors the performance of the motor, as the load and speed changes. In addition, the power required by the fan or pump is proportional to the speed cubed. As shown by the graph below, a small reduction in the speed of the fan or pump results in a large reduction in power.

Problem Statement



The Affinity Law states that the flow in a fan or pump application is proportional to the fan or pump speed. This results in a reduction in required motor horsepower by the cubed change in speed.

$(RPM^1/RPM^2) * FLOW^1 = FLOW^2$

$(RPM^1/RPM^2)^3 * HP^1 = HP$

This reduction is what makes the use of VFDs a substantial energy cost-savings method. Due to the fact that the HVAC system typically is sized for extreme outdoor temperature conditions that occur only a small percentage of the year, reducing the capacity and/or flow of the HVAC system will control comfort and costs. There are multiple methods available to reduce the capacity of the HVAC system, each with some cost-savings capability. The use of a VFD however will result in the maximum cost savings.

With the use of VFDs as a common practice within HVAC systems, manufacturers continually are developing new control methods to increase the efficiency of the system. The introduction of the squared V/Hz ratio reduced the amount of energy used in the motor to create the magnetization current on a variable-torque load. This voltage curve, however, assumes that the power requirements of the motor are exactly a cubed relationship to the speed of the motor. When the load falls below this level, there is an additional energy savings potential. This is achieved by reducing the voltage level to the motor to reduce the magnetization current. However, if the voltage level to the motor is reduced too much, the motor will begin to draw more current. When this occurs, all energy savings possibilities are lost and there is a possibility of overloading the motor. With this possibility, ABB has developed the Flux Optimization algorithm within the VFDs' software to automatically provide the motor with the optimum voltage for any operating speed and load.

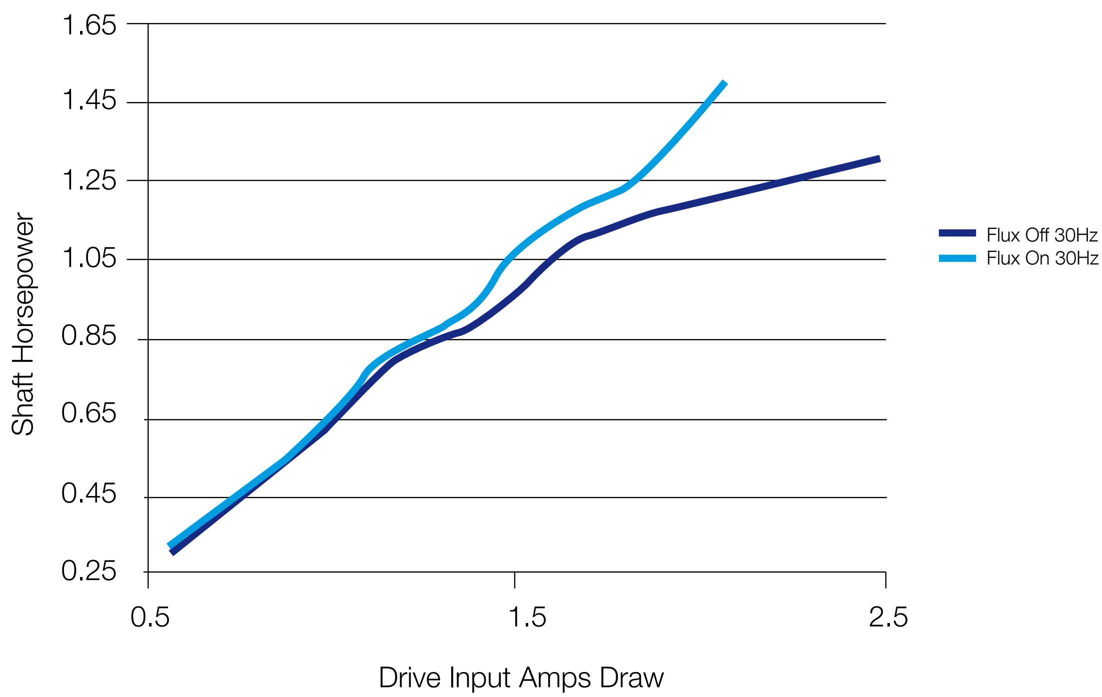
ABB Solution

Flux Optimization is standard function in the ACH550 and ACS550 variable frequency drives. This feature requires no complex programming or configuration of the drive, which makes implementation easy. The software program continuously monitors the performance of the motor, while adjusting the voltage delivered to the motor. With the change in voltage, the motor's magnetizing flux levels increase and decrease.

The Flux Optimization program measures the flux-generating current and the torque- producing current. When operating in scaler mode, data stored in the motor data table is used to adjust the voltage applied to the motor. This continually adjusts the voltage output, as the torque and speed requirement of the motor changes. When the VFD is operated in Vector mode, the VFD will operate in much the same way, but the program will use data measured during the ID run of the motor.

Benefit 1

The first benefit of flux optimization is the reduction of the flux-producing current. This increases the overall efficiency of the VFD / motor package, by reducing the motor's current. ABB conducted several tests of a 3HP 1755RPM motor operated via an ACH550 VFD. The motor was run at three (3) set speeds, while the shaft load was varied from 20 – 100% of full load. The VFD input power consumption was measured approximately 100 times at each. The average of the power draw of the drive for each speed and load was graphed. Below is a chart representing the motor operating at 30 Hz from 0.3 to 1.5 HP. As shown, there is an increase in the amp draw at a given HP at the lighter loads of the VFD operating in Flux Optimization. At 1/3 HP, the flux optimization provided a 2.3% decrease in input power; and, at 1 HP, a 4.2% decrease in input power was measured.



As the load was increased, the motor began to operate near the constant-torque mode. This created a large increase in efficiency, when using flux optimization. This was because the V/Hz ratio was set to the squared ratio, and the drive required additional flux to generate more torque. Flux Optimization has the ability to increase or decrease the magnetic flux in the motor to match the demand of the load.

Benefit 2

As mentioned in the paragraph above, if you operate a motor above the variable torque curve, there is a possibility of greatly decreasing the efficiency of the motor. If the user had set the drive to the squared V/Hz with the Flux Optimization off, the motor would have the possibility of overheating.

When Flux Optimization is enabled, the drive continually monitors the load, and adjusts the voltage applied to the motor as required. This will allow the V/Hz ratio to adjust towards the linear ratio, as required. This also will reduce the energy consumption of the system and protect the motor from over-heating.

Implementation

By default, the ACH550 drive leaves the factory with the flux optimization enabled and a V/Hz ratio of squared selected. This has been geared to the HVAC market and its large use of variable torque loads. An ACS550, however, ships with Flux Optimization off and a linear V/Hz ratio. This has been set to accommodate large use of constant-torque loads in the industrial market.

Summary

The use of Flux optimization has the potential to increase the operation efficiency in variable-torque applications. This is determined by several variables during operation, such as; speed; load; type of motor and size of motor. Because of the nature of the variables involved, the exact energy savings cannot be calculated by ABB. However, test data has shown that there is a possibility of a 5% decrease in input power to the drive when Flux Optimization is enabled. Therefore, the use of Flux Optimization in the ACH550 drive is highly recommended.

Notes

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LVD-PHWP13U-EN REV C. Effective 2/7/2011. Subject to change without notice.