Technical Note 192

Energy optimizer for HVACR drives

What is it & how does it work?

Energy optimizer is a feature that is utilized in variable speed drives (VSD) to help optimally control the motor in the most energy efficient way. This technical note will cover how the energy optimizer feature operates in ABB ACH580 drives and the impact it has in different control modes. There also is some detail on the background of how control techniques have changed to now utilize energy optimization.

Background

VSD manufacturers have implemented various software techniques within drives to manage the voltage to hertz (V/Hz) ratio on the motor output. In scalar control mode drive manufacturers historically would utilize a linear V/Hz ratio. In the HVACR industry where there are primarily variable torque applications, manufacturers have switched to squared V/Hz ratio. This is due to the linear V/Hz ratio often supplying more voltage than necessary for the load. The squared V/Hz ratio means the applied voltage is proportional to the square of the motor's speed. This approach optimizes the motor's output voltage, leading to improved motor efficiency. In industrial applications constant torque is the most common type of application so drives such as the ABB ACS580 still use the linear (V/Hz) ratio as default.

In the HVACR industry, systems are usually sized for design day conditions which is another way to say the warmest day of summer and the coldest day of winter. With variable torque loads the affinity law applies where power is proportional to the cube of the speed. Reducing the speed of the motor results in significant energy savings and increased efficiency. ABB has identified further potential savings in variable torque loads operating at a lower load than expected. The energy optimizer software algorithm continually monitors the motor performance as the load and speed changes and adjusts the drive’s output voltage to the motor as necessary. Energy optimizer in the ACH580 was also present in the previous ACH550 drive but known as flux optimization.

Scalar control mode

Energy optimizer helps save energy when the drive is operating in scalar mode set with parameter **99.04 motor control mode** by controlling the motor flux and optimizing where possible the output voltage to the motor. For ACH580 drives, parameter **97.20 U/f ratio** is set to squared as default. Squared is selected as default because it offers energy savings and more optimal control compared to the linear ratio for a variable torque load.

Energy optimization in ACH580 drives is enabled as standard out of the box and is found in parameter **45.11 Energy optimizer.** When energy optimizer is enabled, there is potential for additional savings compared to the squared V/Hz ratio. The squared V/Hz ratio assumes that the power requirement from the motor is an exactly cubic relationship to the speed of the motor. When the load falls below this level there are extra energy savings available. This is accomplished by adjusting the voltage level to the motor, which reduces the magnetization current. Besides reducing the voltage to the motor, energy optimizer can also automatically boost the voltage to the motor if the motor load requires it.

Vector control mode

When using vector control in **99.04 Motor control mode** Energy optimizer does not have the same effect on motor output voltage control compared to scalar mode. This is due to the motor control algorithm being designed for precision motor control. The setting of Energy optimizer has no impact on how the drive controls the voltage to the motor in Vector control mode. Vector control utilizes data from the motor ID run and controls the flux within the motor providing the most accurate and efficient control.

Where is energy saved?

Energy optimizer is enabled and most effective when controlling induction motors. The majority of the efficiency gains that come from using energy optimization are realized in the motor. See the typical loss breakdown of an induction motor below in Table 1.

Table 1 Losses within an induction motor

Induction Motor Losses	Total Losses
Stator copper Losses	37%
Rotor copper Losses	18%
Magnetic Core Losses	20%
Friction and Windage Losses	9%
Stray Load Losses	16%

Variable losses are stator copper losses, rotor copper losses and magnetic core losses which total 75% of the losses within the motor. These are the losses that can be reduced with the energy optimizer enabled at lower loads. Fixed losses which are friction and windage losses, along with the stray load losses, are not affected by the energy optimizer.

At a given load, lowering the motor current will result in reduced stator copper, rotor copper, and magnetic core losses. Figure 1 below shows the effect on the drive output current at varying load points whilst keeping drive speed constant at 40 Hz, with the **45.11 energy optimizer** enabled and disabled. This particular fan application typically operates around 4.5 kW at 40 Hz. At this operating point, enabling energy optimizer results in approximately 10% lower motor current, resulting in reduced copper and core losses. The reduced losses are another way of saying the motor is running more efficiently because of the energy optimizer. The amount of energy optimization varies based on the motor and load characteristics of the application. As shown in Figure 1, at load conditions near 2 kW the squared U/f ratio is already at the optimum value, thus there are no additional improvements that the energy optimizer can offer. While at other load conditions, the energy optimizer is able to more significantly reduce the motor current.

Figure 1 Behavior of motor current versus motor load at 40 Hz output

Figure 2 shows the data collected with varying load points at 60 Hz (full speed) with the **45.11 Energy optimizer** enabled and disabled. The full load point in this situation is 15 kW. This data shows that there is much less current difference across the load points, which is to be expected as the motor is at rated flux. At full speed, this example shows the motor load must be about half of the motor rating before the energy optimizer provides a meaningful reduction in motor current, and thus reduce the motor losses. Like Figure 1, Figure 2 shows that the effectiveness of energy optimizer in reducing current (and losses) is dependent on the motor and load characteristics.

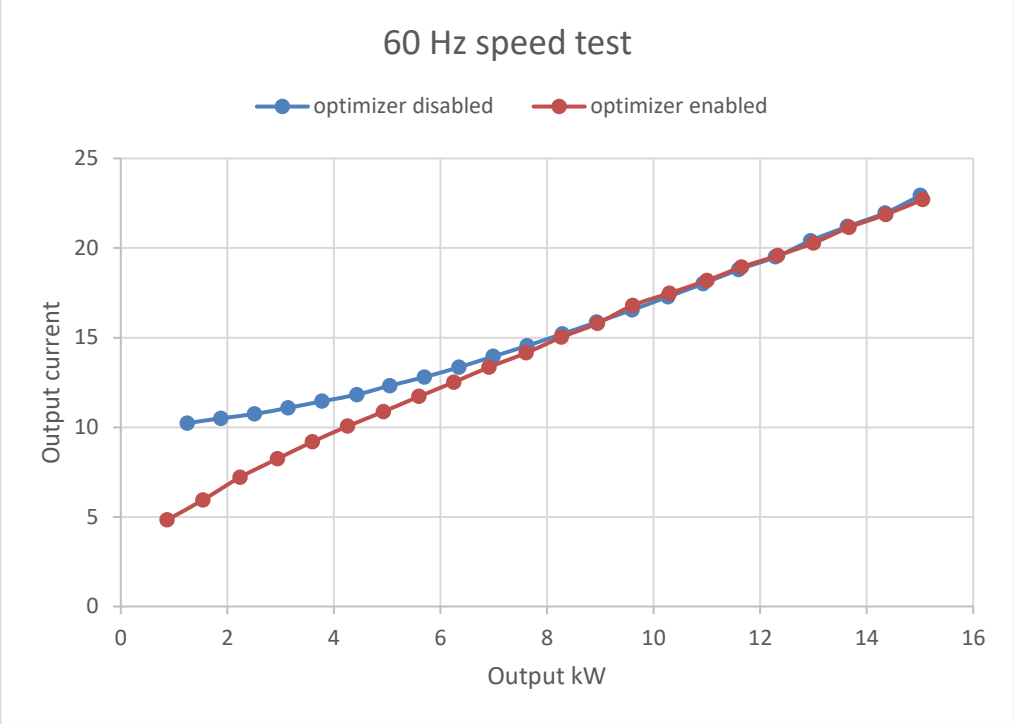

Figure 2 Behavior of motor current versus motor load at 60 Hz output

Exceptions for energy optimizer

In applications such as a fan array sometimes there is requirement for controlling multiple motors with one drive. Where multiple motors are being controlled by one drive it is recommended to have energy optimizer disabled. Selecting multiple motors in the ACH580 setup wizard will automatically turn off the energy optimizer. Energy optimization is in effect automatically enabled when using permanent magnet motors, EC titanium or SynRM motors as it is recommended to use vector control mode and as stated above this control method already optimizes the flux with ID run data and the way it controls voltage to the motor.

Summary

The ABB ACH580 drive has energy optimizer enabled as standard from the factory due to the HVACR market primarily having variable torque applications where scalar mode is used. Energy optimizer constantly monitors the motor load and reduces the required motor flux where possible to save energy. Utilizing the energy optimizer function in variable torque loads such as fans and pumps in the HVACR industry can improve efficiency on the drive and motor package by up to 20% depending on load torque and speed.