White Paper **AP08324001E** Effective February 2010

Evaluating Efficiency and Energy Losses of Various Over-Current Protective Devices

Abstract

Electrical system over-current protective devices (OCPDs) dissipate heat during normal operation. Depending on the type, rating and size of the OCPD (fuses and circuit breakers), the magnitude of energy loss varies. *(Note: Throughout this paper it is understood that the term "fuse" always includes a switching device.)* This paper discusses a test program that quantified those losses for several typical fuses and circuit breakers. The results of this effort show that systems using switches and fuses were found to be less energy-efficient compared with equivalently sized circuit breakers when carrying the same load currents.

Introduction

The devices in an electrical distribution system are a critical part of a facility's infrastructure. These devices include transformers, conductors and over-current protective devices. They are selected based on performance considerations including cost, reliability and safety. The selection of these devices typically includes inputs from contractors, facility owners and engineers. Each of these stakeholders tends to focus on these performance considerations to different degrees.

Cost is always an important consideration for a facility. Everyone understands that these costs include the initial purchase price, the design, installation, start-up costs, etc., associated with a facility. However there may be less obvious costs associated with the ongoing operation and maintenance of the facility. The more energy-efficient a facility is run, the lower the operating costs will be.

As mentioned above, electrical devices contribute in different degrees to the energy efficiency of a facility. Lower-efficiency electrical devices waste more energy, and as a result also contribute to the production of more greenhouse gas. One of these common electrical devices whose energy efficiency should also be evaluated is OCPDs, and this is the focus of this document. In making the choice of either circuit breakers or fuses, the energy efficiency of these two devices ought to be considered. Is there a difference in their energy efficiency?

To answer that question, a study was commissioned to quantify energy efficiency of several types of circuit breakers and fuses. The results of this study show that switches and fuses were found to be less energy-efficient as compared with equivalently sized circuit breakers. These differences in efficiency result in different levels of energy savings. While the absolute magnitude of savings related to the energy efficiency of OCPD may be small compared with other types of electrical devices, the relative differences are very significant. Knowing this difference, why install equipment that you know wastes more energy than another solution?

Study Results

The study was developed to quantify the energy losses for several typical fuses and circuit breakers. Energy losses in fuses and circuit breakers are primarily the direct result of the I^2R resistive loss effect of the current flowing through the resistive elements of these devices.

As its name suggests, resistive losses are defined as:

Equation 1: $W_{loss} = I^2R$

Where:

- W_{loss} = energy loss in watts
- I = current in amperes
- R = resistance of conductor in ohms

From Equation 1, we see that the resistive energy losses in a device are proportional to the resistance of the conductors within a device. For the same current flowing in two devices, the device with the higher internal resistance will have greater energy loss, which may result in a higher device temperature. However, temperature rise alone is not a reliable indicator of losses. Energy losses are best determined via the I^2R energy loss in these devices.

Manufacturers of electrical products must meet third-party certifications ①. Many of these certifications specify temperature rise limits of bus, terminal lugs, coil windings and/or conductors. In order to meet the specified temperature rise limits, some manufacturers use the options of adding heat sinks or specifying larger products. Therefore, although these devices may have higher internal energy losses, these options allow the devices to still meet the specified temperature limits.

Powering Business Worldwide

① Several UL standards specify temperature limits for protective devices and assemblies of protective devices including UL standards 198, 489, 891, 1558 and many others.

Evaluating Efficiency and Energy Losses of Various Over-Current Protective Devices

To ensure that we understood the actual energy losses within circuit breakers and fuses, a test program was developed to measure the losses from each of several types, brands, sizes and ratings of circuit breakers, fuses and switches. The test program attempted to study as many combinations of the various types, brands and sizes that are currently available. The test looked at fuses of types RK-5, J and L, Molded Case Circuit Breakers (MCCB) and Air Circuit Breakers (ACB), and over-current range of 20 to 5000 amperes. Although attempts were made to be as comprehensive as possible, it was not practical to study every possible combination of these types and ratings of devices. Instead, the test focused on ensuring that an "apples-to-apples" comparison was done on equivalent devices—tests compared devices of the same rating.

The details of the specific test methodology and combinations of devices that were tested and their test results can be found in Eaton® Technical Paper *AP08324002E*.

As a result of theses tests, the differences in watts losses (W_{loss}) between several types of circuit breakers and fuses were noted. These differences are noted in **Table 1** below.

Table 1. Percentage watts-loss differences between various types of circuit breakers and fuses

Comparison	Ampere Range	3-Phase Watts Losses
Molded Case Breaker versus RK-5 fuses	20–600 A	Fuse dissipated, on average, 121% higher losses than MCCB of same size and rating
Molded Case Breaker versus Class J fuses	20–600 A	Fuse dissipated, on average, 91% higher losses than MCCB of same size and rating
Molded Case Breaker versus Class L fuses	800–2500 A	Fuse dissipated, on average, 226% higher losses than MCCB of same size and rating
Fixed Mounted Air Circuit Breaker versus Class L fuses	800–5000 A	Fuse dissipated, on average, 434% higher losses than MCCB of same size and rating
Draw-out Air Circuit Breaker versus Class L fuses	800–5000 A	Fuse dissipated, on average, 148% higher losses than MCCB of same size and rating

When the differences highlighted in **Table 1** are viewed graphically in terms of absolute watts, the differences appear as shown in **Figures 1 & 2** in the next column:

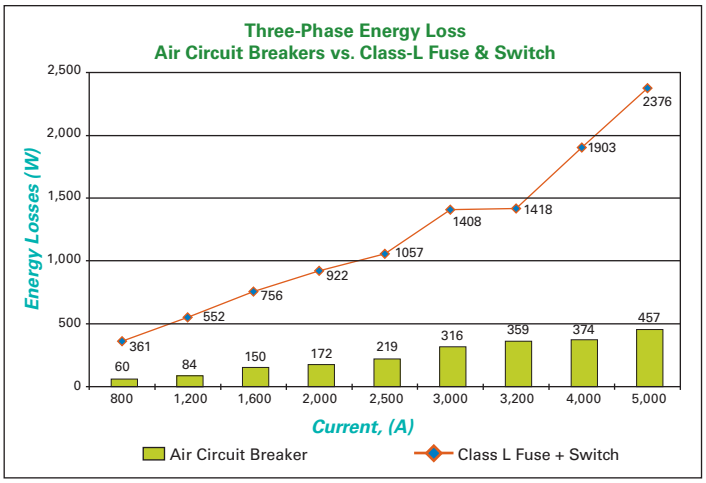

Figure 1. Watts loss comparison—Air Circuit breaker vs. Class L Fuse & Switch

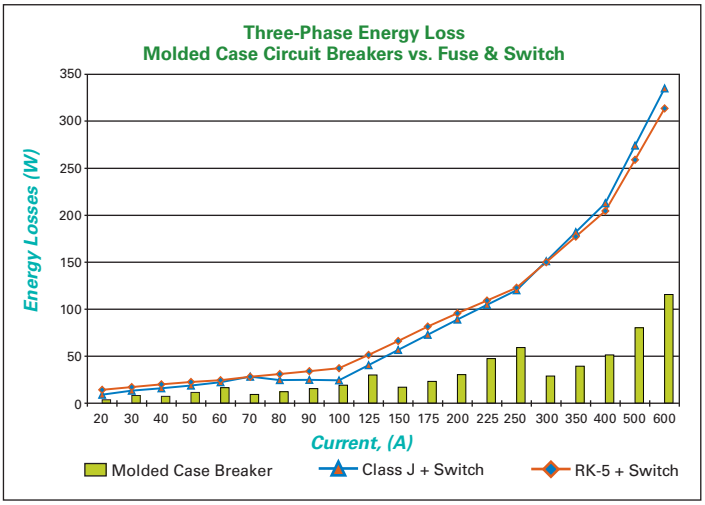

Figure 2. Watts loss comparison—Molded Case Circuit Breakers vs. Class J & Class RK-5 Fuse & Switch

Conclusion

The energy efficiency of the electrical distribution system of a facility typically contributes significantly to the operating costs of that facility. Different types of electrical devices have different levels of cost impact. Some devices have a significant impact, while others have a lesser impact. The more energy-efficient an electrical device is, the lower its operating costs will be. In the design and implementation of the system of over-current protective devices that are to be used in a facility, choices in the types of these devices must be made. In making these choices, in addition to other performance factors and commercial considerations, system designers and facility owners should also consider the energy efficiency of the two basic options—fuses or circuit breakers. Is one of these devices more energy-efficient than the other?

A study was conducted to evaluate the relative energy efficiencies of a range of fuses and circuit breakers. The data from this study showed that, on average, circuit breakers are appreciably more energy-efficient than fuses. With this fact in mind, designers and facility owners are able to include this consideration when looking at the various other performance factors for selecting the type of over-current protective devices to be used in a facility.

Eaton Corporation
Electrical Sector
1111 Superior Ave.
Cleveland, OH 44114
United States
877-ETN-CARE (877-386-2273)
Eaton.com

Printed in USA
Publication No. AP08324001E / BC-10
February 2010

Powering Business Worldwide

PowerChain Management®