UNDERSTANDING ELECTRIC PROPULSION SYSTEM POWER RATINGS

Each day, Americans rely on dozens of appliances and systems to fulfill basic needs. Heating, cooling and ventilating homes and offices, pumping water, washing clothes and dishes, and vacuuming all involve moving air, liquids or objects in a circular motion. None of it would work without electric motors. Each day, thousands of engineers, technicians, mechanics, managers and salespersons and others go to work to design, sell, manufacture, assemble, test, and service these motors in a dynamic and competitive industry worth billions of dollars. As in any business, these individuals need a commonly understood language to describe the performance and capabilities of different types and sizes of electric motors so that an appliance maker, for example, can select a motor with assurance that it will perform as required. This need arose as part of the transition in the 19th century from one-off "craft" manufacturing to standardization of parts. For parts to be interchangeable, they need to be "rated". A rating is, essentially, a promise of performance capability. Today, nearly everything we buy has a rating of some kind. In some cases, ratings are straightforward, like insulation values and fire resistances for building materials. Rating electric motors, however, involves greater complexity. Buyers therefore need to understand the differences among motor applications and ratings in order to make "apples-to-apples" comparisons among differing types and manufacturers and to arrive at a selection that best fits their needs.

For just about everything electrical, heat limits performance. Even the best conductors of electricity have intrinsic levels of resistance to the flow of electrons through their molecular structure. Electrical engineers therefore devote many hours to solving problems related to minimizing and managing the heat that's generated as a byproduct of whatever the circuit or system they are designing is intended to do. These problems exist at the tiniest dimensions within microprocessor chips as well as at the largest electric power generating stations. Engineers take advantage of the fundamental properties of heat to solve these problems. One of these properties is the "slowness" of heat compared to other forms of energy. Anyone who has waited for a kettle to boil or a cold house to warm up has experienced this. Engineers also use information about the nature of the job that the circuit or system has to do as part of the process of figuring out how to deal with its heat issues. In the case of electric motors, heat can be such a significant issue that differences in the specifics of what the motor has to do, when and for how long can greatly affect the size and cost of the motor chosen. Among the most important of these differences is whether the motor has to run continuously or in short "bursts" in between idle periods. Engineers coined the term "duty cycle" to characterize systems like motors in terms of the amount of running time within a given interval. A system that runs all the time has a "100% duty cycle" while one that operates for a total of 6 minutes every hour has a 10% duty cycle.

By mixing these two ideas – the relative slowness of heat, and the concept of a duty cycle – an effective strategy for managing heat in electrical systems becomes apparent. Because the heat build-up within an electrical system takes time, those with low duty cycles will, to some degree, cool down naturally in between their operating periods. As a result, they need less in the form of components to actively remove heat. Systems with high duty cycles, on the other hand, have less time to naturally cool down. Meanwhile, not all systems run in purely on/off manner. Instead, they operate at varying levels of exertion – what engineers call “load”. So in addition to considering a system’s duty cycle, engineers also determine the maximum load a system has to contend with as well as the percentage of this maximum load that is actually present at different times. Different applications vary greatly not just in duty cycle but in load levels present during “on” times. A household coffee grinder provides a good example – it’s unused most of the time, and when it is used, it needs less than a minute to grind enough coffee for a full pot. It would therefore make no economic sense to design a coffee grinder with a motor capable of continuous operation. At the other end of the spectrum, consider the problem of keeping the millions of file servers, routers and storage devices in data centers from overheating. They run 24/7, and while the facility that houses them can sometimes use outside air and other strategies to save energy, fans and pumps still need to operate continuously to maintain a suitable environment. This is an example of a 100% duty cycle application which the motors that drive the pumps and fans must be able to contend with. These motors cannot be designed so as to rely on downtime to keep themselves cool.

After years of research, product development, testing, troubleshooting, standards writing, and even litigation, engineers have settled on the terms “continuous” and “peak” to differentiate between ratings for systems that operate continuously at or near full loads and those that operate at some combination of low load and low duty cycles. Of the two, continuous ratings are both lower and more solidly defined. An AC motor rated X kilowatts continuous, for example, is universally understood to mean one that can operate indefinitely at that level. The rating may be accompanied by qualifiers such as acceptable ranges of the temperature and humidity of the surrounding air, the voltage, frequency and quality of the incoming power, etc. But these qualifiers do not trump the basic validity of the rating. Peak ratings, in contrast, beg the question – how do you characterize the peaks, e.g., 30% maximum duty cycle or 70%, at 40% load or 75%? This question is highly relevant for designers of electric vehicles, where costs are high, power requirements are large and speed and acceleration vary – think race cars vs. wheelchairs. For electric boats, additional considerations arise, such as environmental conditions and the prospect of being away from help when something goes wrong.

At CeMA, we have long held the view that boat owners and operators deserve the clarity and simplicity of continuous ratings when selecting electric propulsion equipment. We would rather spend more time helping them understand how to get most out of their investment and less time constructing elaborate combinations of duty cycle and load limit graphs to justify higher peak ratings. Although a skipper of an electric boat might often not need to use all of the continuous rated power of the system, he or she should be able to count on it in tough conditions without having to remember that it needs a rest from time to time in order to avoid overheating. Some of our competitors, meanwhile, have opted to use peak ratings. This, unfortunately, injects confusion into the marketplace such that boat owners and operators need to educate themselves on these issues in order to compare the products of different manufacturers on an equal basis. To help in this regard, the accompanying sheets depict the products of competitors who use peak ratings in relation to CeMA products on a continuous-rated basis. We had to make some reasonable assumptions in order to do so, and we look forward to learning more about how they calculated their peak ratings.

David M. DiQuinzio, PE
CTO
CeMA