

Understanding Machinery Electrification

Creating A Successful Machine Electrification Project

As the trend toward electrification of mobile equipment accelerates, it is becoming increasingly apparent that simply looking at the power rating of the current Internal Combustion Engine (ICE) and using that to assume battery power requirements is not enough. In most cases, this leads to an overestimation of the piece of equipment's battery needs which can be a very costly mistake, and in many cases make the project financially unfeasible.

Understanding the System Design – Hydraulic Efficiency

The first step to launching a successful electrification project is to understand the power requirements of each individual function on the machine. Why is this important? In many cases, hydraulic systems have not been designed to be as efficient as possible, but rather to get the job done at the lowest possible cost. This is not poor design, but rather a reflection of the need to balance design elegance with costs, which are critical in most markets. Because of the costs of electrification components, it becomes much more important to right-size each individual actuator in order to ensure maximum efficiency, and to correctly size your battery pack.

Consider a simple example where a machine uses a single cylinder to perform some function. In this example, 5 GPM@3000PSI is required to deploy the cylinder and we are using a simple fixed pump system design that actually generates 10 GPM.

Hydraulic Horsepower is calculated as:

$$HP = P \cdot Q / 1714$$

where:

P – Pressure in PSI

Q – Flow in GPM

In this example the system would be dumping 5 GPM over the system relief at 3000 PSI which equates to 8.75 HP in wasted energy during the cylinder cycle. While this example is certainly oversimplified for most machines, it illustrates a very important concept: many current system designs can result in significant wasted energy, which can be a very costly mistake in a battery powered system.

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Understanding Duty Cycle

The next step in a successful electrification project is to truly understand how a machine is operated. While this may seem overwhelming, it is important to instrument the pressure and flow at each work function and run the machine under real-work operating conditions. A few hours of data recording will yield useful information regarding peak loading and duration. You can easily oversize electric motors if you size for peak loading only, and not take into effect work cycle duration. To properly size an electric motor, let's take a look at the following example:

Motor A – with data recording, you determine that a work function requires 17.17 gpm at 2000 psi. The current hydraulic motor is running at 2500 rpm. Based on these data points, you can calculate motor kW, and torque required.

$$HP = \text{Pressure} * \text{Flow} / 1714$$

$$HP = 2000 * 17.17 / 1714 = 20.04$$

$$kW = HP / 1.341$$

$$kW = 20.04 / 1.341 = 14.94$$

$$\text{Torque} = 9.5488 * \text{Power (kW)} / \text{Speed}$$

$$\text{Torque} = 9.5488 * 14.94 / 2500 = 0.05706 * 1000 = 57.06 \text{ Nm}$$

Now that you have calculated motor torque and power required, the next step is to understand how often and for how long this machine function is used. For example, does motor A run the boom on the machine for 2 minutes every 25 minutes? Does one type of user run the boom for 5 minutes every 15 minutes, and someone else runs it differently? All of these factors, peak loading and duration, and how a machine is used, determines how to size your battery pack for battery system optimization.

Battery System Optimization

For most electrification projects, the size of your battery pack is the largest cost driver, and can make or break its feasibility. In order to optimize your battery system, understanding the power requirements, and duty cycle of your machine can then be used for a very accurate estimation of battery capacity requirements. Keep in mind that most battery packs are identified by their kWh capacity. To understand what capacity battery pack you will need, see the following example using motor A from above;

Motor A – with data logging, it is utilized for 25 minutes in a given work hour. For the other 35 minutes in an hour, it is not used. Based on this....

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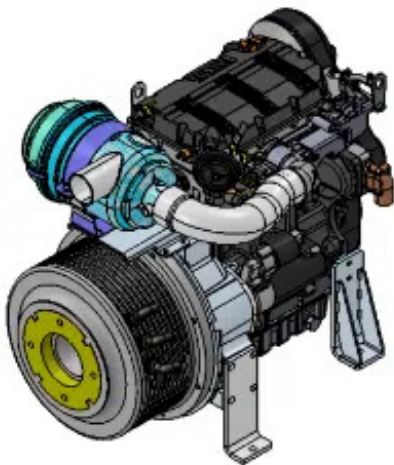
*kWh = power required (kW) * duty cycle per hour*

*kWh = 14.94 kW * (25 mins/60 mins/hr)*

*kWh = 14.94 kW * .42 hr*

kWh = 6.27 kWh

Taking this 6.27 kWh figure, and with an understanding of how your machine is utilized, you can optimize your battery system. If your machine is utilized for 6 hours of work out of an 8 hour work day, then you will need a battery pack that has a capacity of 37.62 kWh (6 x 6.27 kWh).



Another thing that needs to be considered is how you will be recharging your battery pack. For the above example, during that 8 hour work day you may have some time to plug in an on-board charger for an hour or so over lunch which could possibly allow you to get away with a slightly smaller capacity pack or a longer work cycle. Another option would be to incorporate some type of generator/alternator that could be utilized to and from job-sites that would allow for additional charging and a smaller battery pack.

There is also the possibility of using a small auxiliary combustion engine/generator combination for charging your battery pack during peak requirements reducing the capacity size of your battery pack. Figure 1.1 here is an example of a 24.5 HP diesel engine with a flywheel mounted 10kW generator.

Summary

If you are a machine OEM, the requirement to electrify your machine is being driven by multiple factors including governmental regulations, growing climate awareness, emission standards, and even local noise ordinances. As battery technology continues to advance in power density, and costs less, the drive to electrify will only continue to grow. To make these projects feasible, you have to optimize your equipment. To do this, you must understand the duty cycle of your machine to properly size components. You need an integrator that understands this optimization, and can implement solutions that make sense for you. To talk with our electrification experts, contact Cross Mobile Systems Integration today.