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HYBRID™ READY

Application Note

Using Power Systems to Enable Hybrid Modes

UAV designers face a range of tradeoffs. The mission profile determines the payload and operating parameters which determines other factors such as propulsion method and electrical power requirements. These decisions should not be made in isolation. There are ways to design in synergies between the propulsion system and the power system to create a lighter and more efficient aircraft. This approach draws on hybrid designs but does not require continuous hybrid operation to be effective.

Sizing the Engine

Internal combustion engines still provide the most efficient propulsion system for many UAV applications. The power density of fuel remains the most appropriate option for many propulsion applications. Gasoline has about 100 times the energy density of lithium-ion battery. Therefore, many defense, security and commercial mission profiles use only internal combustion engines.

The weight of the UAV is a function of many factors. Ultimately the payload required for a given mission determines the requirements for the airframe and the other systems. The payload is a major factor in the weight of the aircraft. It also has a major impact on the electrical power requirements of the aircraft. The weight of the electrical system including the battery is also a function of the mission parameters, payload, and other requirements.

The mission parameters will also determine systems like avionics. Avionics will also have specific power requirements. All the systems on board will have a range of power requirements that must be met in the UAV design.

UAV designers face an interesting dilemma; the power requirements for takeoff and for steady flight are fundamentally different. This can result in an engine that is not as fuel efficient as possible for steady flight. This can add weight, reduce flight time and cost to the aircraft design.

An Intelligent Hybrid Power Assist Unit (iHPAU™) provides a means of resolving this problem. An iHPAU™ comprises an internal combustion engine, a combined starter generator & propulsion motor and an Intelligent Electronic Control Unit (iECU). The iECU has a built-in electronic engine starter and an intelligent Air Motor Controller (iAMC). It is possible to change the starter generator from a power generation mode to a power assist mode. Essentially, the starter generator draws power from the battery and utilizes this energy for propulsion thereby supplementing the engine in propulsion mode.

The Need for Power Systems

The internal combustion engine obviously cannot supply electrical power directly. First an alternator or starter generator is required. Technically, these are different electrical machines performing a similar function in supplying electrical power. A starter generator differs from an alternator in that it has sufficient torque and power to also start the engine from the onboard battery power. Incorporating an electronic engine starter as a component of the power electronics eliminates the need for separate external starters.

Once running up to speed, the starter generator must be sized to generate the appropriate electrical power budget for the payload avionics and ultimately the mission parameters. The starter generator captures mechanical energy from the engine to provide 3-phase AC power output.

Power electronic systems are matched to the starter generator to convert AC to DC for on board avionics and to charge the battery. Power electronics such as an Intelligent Power System (iPS) take the DC power and break it down to the net appropriate voltages for the various systems within the UAV.

Considerations for Power Assist

There are several considerations that the aircraft designer must take into account. First, the battery needs to be sized appropriately. Typically, the battery will be fully charged at the beginning of the mission which facilitates this. Second, the starter generator needs to provide sufficient additional power to assist in takeoff. The designer must consider the relative power requirements of take off in steady flight. Third, as noted previously, the appropriate electronic engine starter must also be in place on the aircraft. It is important to note but the starter generator must be sized to have enough torque to turn over the engine when starting it and to reach cranking speed at the required engine torque in seconds.

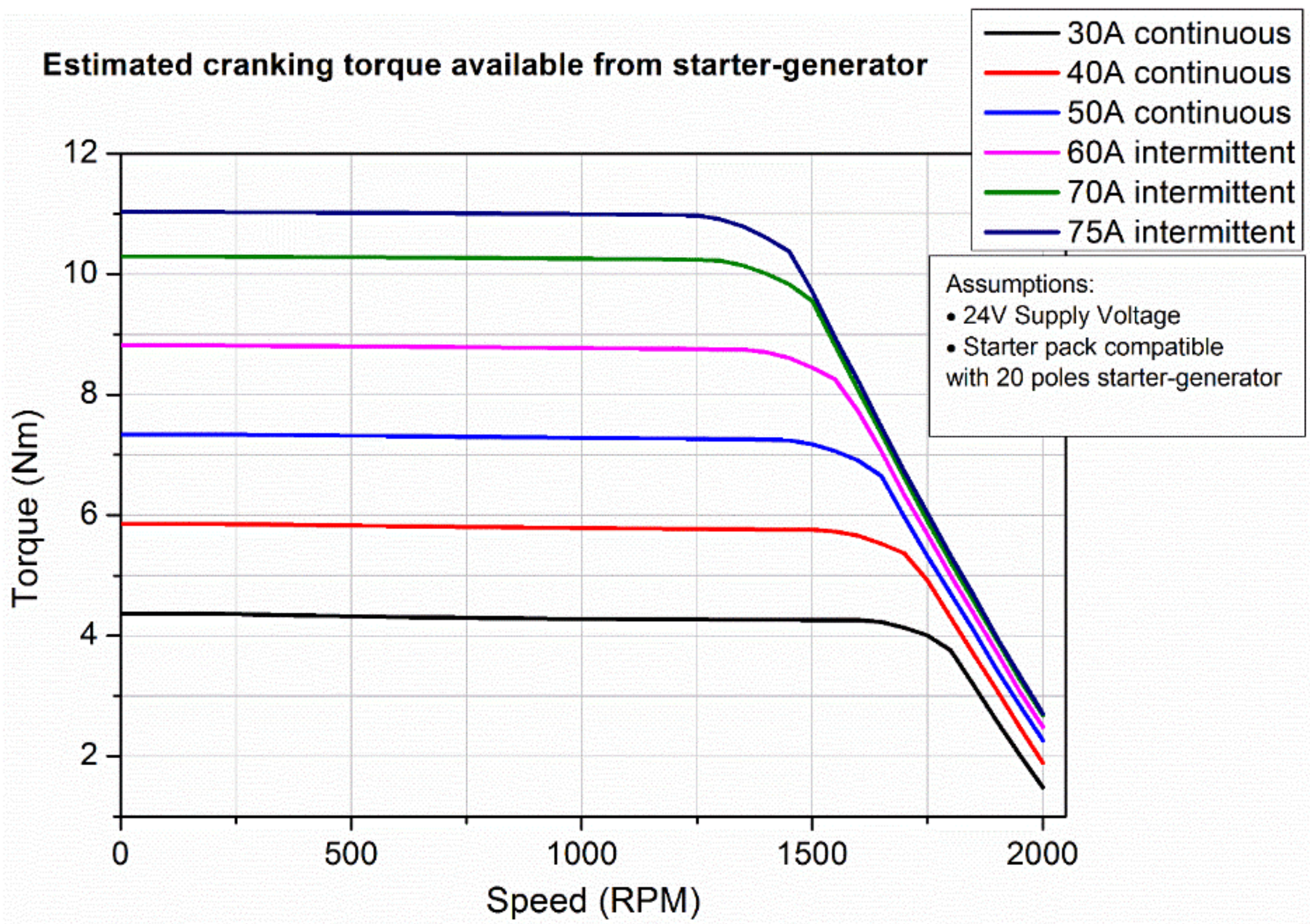
Using an example scenario, a starter generator when mounted to an Internal Combustion Engine (ICE) must be able to provide the following:

1. Initial torque to overcome compression when at zero speed to start spinning.

2. Required cranking torque at the required cranking speed. For example, if the torque required is 15Nm at 2000RPM for 5 seconds, about 3.14kW of power would be required for this specific engine to crank.
3. In order to achieve the required cranking torque and speed, a certain minimum current, around 112A from the batteries at 28V, is required.
4. The initial torque to overcome the compression may be much higher depending on the temperature of the engine. A cold start will always require much higher torque to overcome compression. In some cases this torque can be twice as much as the nominal cranking torque.

A Torque Speed Graph of a starter generator should show if the above requirement is achievable for a certain size SG. The example graph shows that a 10Nm torque was achievable at 1000RPM using 24Vdc and about 70A.

Figure 1. Estimated cranking torque available from starter generator



It is important to note that the SG will not charge the battery if the ICE is running below a certain RPM. For example, when a given ICE is running at 3000 RPM, the SG will produce 30Vdc output after its 3-phase has been rectified. The 30Vdc will be able to charge up to 7 LiPo cell pack, each cell being 4.2 volts. Now if the RPM drops to 2500RPM the rectified voltage may drop to 25Vdc and the 7-cell pack will not be able to charge as the charging voltage has to be higher than the fully charged voltage level.

This illustrates the importance of properly matched power system components including the SG, PMU and EES. ePropelled can assist in finding the correct components for your application.

Use Cases

The first use case for power assist using a starter generator as a propulsion motor to provide sufficient power to assist the internal combustion engine during takeoff. This allows the internal combustion engine to be sized for steady state flight rather than sized exclusively for peak power requirements at takeoff. We refer to this as power assist. The power pack is called Intelligent Hybrid Power Assist Unit (iHPAU™)

A second use case can be achieved with the same parameters. Battery power can be used to extend flight time. This provides a mechanism to use the battery power to land the aircraft in the event of a fuel emergency.

A third use case would be using electrical power only temporarily for reduced noise.

The aircraft designer must account for these requirements or options in the design process. As noted, the appropriate starter generator and power electronics must be selected. The battery must also be sized to support this application. most importantly, the control systems must be in place to support this.

The electrical power system is a required element in the aircraft design. While it does add weight, this could be offset by utilizing it as a power assist or range extender as an integral part of the aircraft systems design.

For more information about ePropelled, please visit the ePropelled webpage.

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