DEVELOPMENT OF HYBRID GASOLINE-BATTERY PROPULSION SYSTEM FOR MULTI-COPTER PLATFORM

Hyuk Rok Gwon*, Woo Bee Kim*, Ki Woong Lee*, Dae Won Kim*, Hyeon Seok Lee*
***Korean Air R&D Center**

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Abstract

In this study, we focus the gasoline-battery type hybrid system. We propose that the series gasoline-battery hybrid propulsion system for multi-copter UAV (Unmanned Aerial Vehicle) platform. The two stroke gasoline engine – generator module is operated continuously and generated the AC electricity. In order to improve performance, key technologies such as DC voltage supply without regulator, starting / generating mode smart switching technologies are supplied. The multi-copter prototype is assembled with hybrid propulsions system and commercial off-the-shelf (COTS) sub parts. Finally, we developed maximum 5 kW generative hybrid gasoline-battery propulsion system for the multi-copter platform. With this propulsion system, the UAV endurance can be increased from 30 min to 120 min.

1 Introduction

Multi-copter unmanned aerial vehicle (UAV) is revolutionized flight. Nowadays, the multi-copter UAV has several practical applications for public / civil / commercial region such as suspect tracking, monitoring large crowds, inspecting the infra structures, agriculture management, and media accessing to hard-to-reach place, etc [1-3]. Although these various applications, the downside of multi-copter UAV is their limited endurance around 20~30 minutes due to low energy density of battery [4].

For this reason, several researchers have suggested and developed many types hybrid propulsion system with combining of two or more distinct propulsions system, such as, gasoline engine, battery, fuel cell, solar photovoltaic cell, etc. The fuel cell and solar photovoltaic cell techniques are eco-friendly, robust. However, there are currently some technical barriers to overcome for commercializing the hybrid propulsion system with the fuel cell and the photovoltaic cell technique [5]. The fuel cell system still has hydrogen storage issue, fueling problem with related system maintenance cost. The energy density and power density of the photovoltaic cell are significantly low than other energy sources. Therefore, in this study, we focus the gasoline-battery type hybrid system. The proposed hybrid gasoline-battery propulsions system consisted with power management module, battery module, engine-generator module. In this proposed system, the high energy density characteristics of gasoline engine and the high power density characteristics of battery are combined.

In this paper, we propose that the series gasoline-battery hybrid propulsion system multi-copter UAV platform. In that hybrid propulsion system can generate maximum 5 kW electricity.

2 Hybrid Propulsion System Configuration

Figure 1 shows the brief configuration of the proposed gasoline-battery hybrid propulsion system. In a series hybrid configuration, the propeller is only driven by the electric motors. The mechanical power of the internal combustion engine is converted into the electric power by a coupled generator. It is used either to directly provide power to propulsion motor or to charge the battery. The advantage of the series configuration is that the engine is completely decoupled from thrust generation and can hence constantly run via optimum engine operating point [6]. Furthermore, the simplicity of the concept allows an easy propulsion control. As shown in Fig. 1, the hybrid propulsions system has 5 typical sub-parts: propeller with electric motor, combustion engine with generator, battery, and power management unit (PMU).

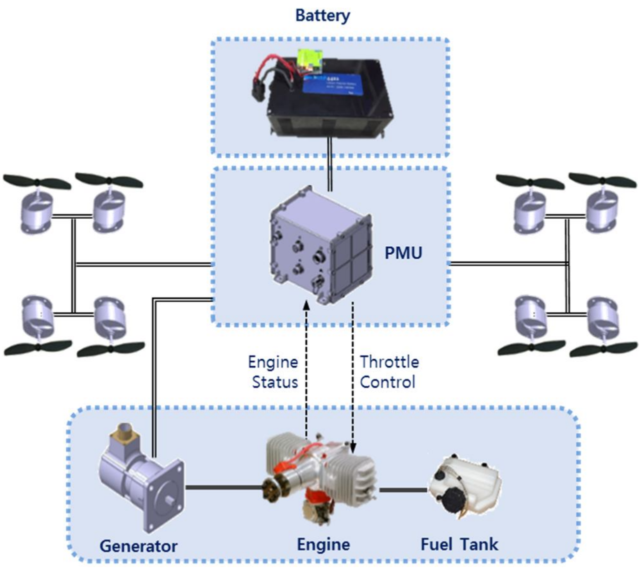

Fig 1. Entire configuration of proposed gasoline-battery hybrid propulsion system.

Eight electrical motors and 30 inch two blade propeller used for MTOW coaxial quad-copter UAV. We use 12 HP 2 stroke gasoline engine and PMSG (Permanent Magnetic Synchronous Generator) is used for electricity generation. Lithium-polymer battery is used for remote engine starting and auxiliary power unit of the UAV. And the developed PMU manages the entire required power consumption and generation. The PMU receives the signals from engine (RPM, cylinder head temperature, throttle position) and control the throttle for power management.

2.1 Engine-Generator Module

In hybrid propulsion system, the internal combustion engine converts the chemical combustion energy in gasoline into shaft rotational mechanical energy. We used the commercial 120 cc two stroke spark ignition engine. The engine shaft rotational mechanical energy converts to electrical energy with connected generator. The engine shaft and generator shaft directly connect with flexible diaphragm coupling for damping heavy engine vibration due to combustion. The KV of generator was modified for generating appropriate AC system voltage.

2.2. Power Management Module

The power management module is consisted of current sensors, voltage sensor, rectifier, reverse diode, battery and PMU. Figure 2 shows the schematic of power management module in proposed hybrid propulsion system.

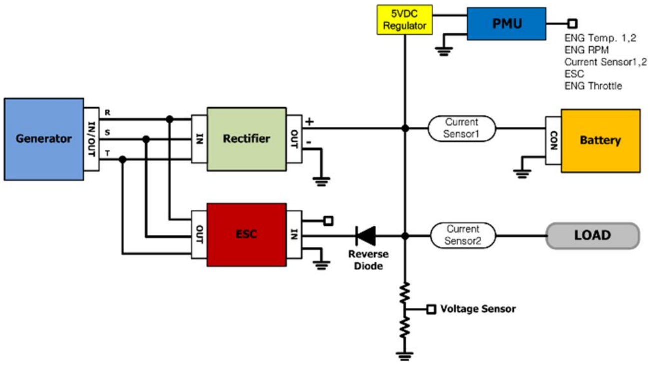

Fig. 2. The electrical diagram of power management system.

Table 1. Specification of items

Items	Specification
PMU	ARM Series CPU
Battery	Li-Po
Rectifier	3 Phase
Current Sensor	Bidirectional
Voltage Sensor	Register distribution

The specification of items is listed in Tab. 1. In our power management system, there are two key technologies. First of all, the constant DC voltage is generated without regulator. In generally, the generation voltage with engine-generator system may fluctuate according to engine operating RPM. Therefore, the high power and heavy regulator with buck-boost converters is essentially needed. However, the suggested design makes it possible to realize reducing weight of system. Without the regulator, the constant DC voltage is generated by connection a rectifier output with a battery that acts a role as voltage damper.

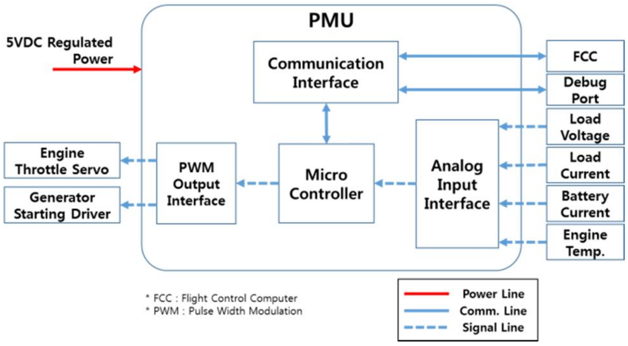

Fig. 3. The architecture of PMU hardware.

Secondly, this system suggests the simplification of the starting / generating mode switching of 3 phase output generator. Usually an engine is started with several times of spark ignition via a starter motor rotation. After an engine starting, a generator is operated by an engine rotation toque. In this system, a generator performs both functions of an engine start motor and a generator. Therefore, the switching circuit generally used for the protection of the generator starting driver. Because of the freewheeling diodes operated as rectifier in generating mode without switching circuit. However, instead of the complicated mode switching circuit, the reverse diode is installed in this study. This technology makes it possible to reduce the control factors from the switching circuit and protect the generator starting driver.


Fig. 4. The developed PMU hardware.

The suggested hybrid gasoline-battery propulsion system is operated by the active system power control technology by using the PMU. The PMU hardware is developed as a prototype circuit that consists of a micro controller and analog input / pulse width modulation (PWM) output / external communication interface as shown in Fig 4.

To track and manipulate the system load current, the PMU controls the engine speed automatically with throttle position adjusting according to measured load voltage / current and battery charging / discharging current. The throttle position can be controlled with servo motor. The PMU has several functions such as engine starting driver control, engine throttle servo control, CAN Communication with flight control computer (FCC, command & status), RS-232 communication for debugging, hybrid propulsion system monitoring (load voltage / current, battery charging / discharging current, engine cylinder head temperature (CHT), engine RPM).

2.3 Supporting Structure

According to use the two stroke spark ignition engine, system vibration level is very high. Therefore, it is very important to design appropriated supporting structure to reduce and absorb the vibration from the engine operation. In this study, the supporting structure is composed of two assemblies, engine-generator module supporting structure and hybrid propulsion system supporting structure. The engine-generator module supporting structure is attached to hybrid propulsion system supporting structure with 8 absorbers to damp engine vibration. For enduring vibration of engine, the engine-generator module supporting structure is made of aluminum. Each mount and stringer structure align the engine shaft and the generator shaft. To minimize the shaft fracture caused by mismatch of two shaft rotating axis, generator mount is designed to attach reverse direction.

3. Hybrid Propulsion System Test

In order to test the power generation performance of proposed hybrid propulsions system, we used the electrical load system. The electrical load system can support electrical power to hybrid propulsions system up to 9 kW / 1.8 kA with high speed response. With this electrical load system, we tested the maximum power generation test of proposed hybrid propulsion system. Figure 5 shows the electrical load and generation power with respect to operating time. The engine-generator module appropriate generate and well follow the required electricity, and maximum generation electricity is about 5.177 kW at 6,290 RPM. It is confirmed that the developed PMU operate perfectly for controlling the engine speed automatically with throttle positioning. The red line shows the required electrical power from electrical load and the blue line shows the generation electrical power from the engine-generator module.

4. Conclusion

We developed gasoline-battery hybrid propulsion system for multi-copter platform. It is designed and fabricated with several modules such as the engine-generator module, the power management module, and supporting structures. With the developed hybrid propulsion system, the maximum 5.1 kW power generation test was demonstrated with the electrical load system. Consequently, it is found that our PMU operated perfectly and entirely system works properly.

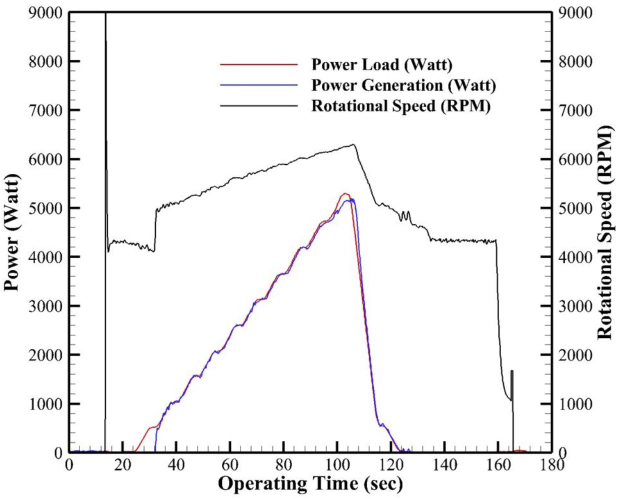

Fig. 5. Maximum power generation test result.

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Contact Author Email Address

hrgwon@koreanair.com

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