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Uninterruptible Power Supply Design for Heavy Payload Tethered Hexaroters

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ABSTRACT

This Research addresses the uninterruptable power source (UPS) design problem for power conversion on tethered unmanned aerial vehicles (UAV). The prototype UAV used in this research is a heavy payload tethered hexarotor that serves long flight missions in agricultural automation and remote sensing. The proposed UPS unit is capable of instantaneous protection from input power interruptions with smooth and safe power shifting from noisy nonlinear switching regulator based output power to stored battery power at low voltage side, mounted on UAV. Low altitude with heavy payload makes the design very challenging as this requires very high current rates followed by a high speed power failure detection and shifting to UPS, for safety operations and emergency landings of UAV. In this design we connect offline UPS with fast solid state relay and very high current fast switching diodes to into low voltage bus bar of tethered hexarotor. Proposed design altogether with high payload tethered hexarotor is a unique engineering achievement.

Keywords: Uninterruptible Power Supply, Tethered Hexarotors, Heavy Payload UAV, DCDC Power Conversion on UAV.

INTRODUCTION

This paper address Uninterruptible Power Supply (denotes UPS) mounted on unmanned aerial vehicles. The unmanned aerial vehicle (denotes UAV) used in this research is a heavy payload tethered hexarotor for long time hovering at low altitudes. Research [2] introduced a basic design problem for heavy payload tethered hexarotor and in research [1, 7] address in detail the high to low DC power conversion unit design problem for heavy payload tethered hexarotors. To simplify the introductions, we add figure 1 and figure2. Figure 1 illustrates the tethered hexarotor where the proposed UPS will be mounted and figure 2 illustrates the tethered hexarotor system.

Power conversion on UAV is 380VDC to brushless DC motor operating voltage 48VDC. Considering the weight limitations on DCDC power conversion modules it is necessary to use switching regulators as DCDC converters. Switching regulators inherit nonlinear features as high frequency transient or oscillation, current and voltage spikes, harmonics and distortions. Notwithstanding during this hexarotor developing project we have to parallel DCDCs to achieve the required power. Since parallel configurations improve the system thresholds by preventing each DCDC module operating close to the each module's operating thresholds.

Paralleling switching regulators under normal circumstances cause increase in nonlinearities. Common problems are such that delays in powering up or powering down of either regulator would cause a back-feed from a high output DCDC to a low output DCDC, i.e. possible sequencing problem to avoid oscillations. For reliable operations better synchronization and sequencing features are necessary than simple impedance matchings. In this research project we adopt full parallel forward current configuration to achieve high current for the high payload lift task. Validation tests on the parallel configurations already cleared the existing thresholds.

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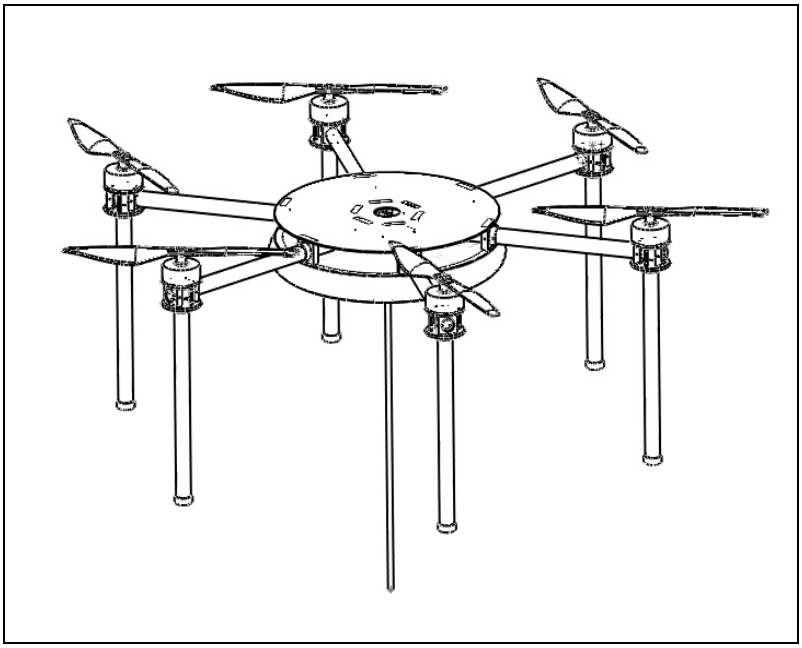

Figure1. *Tethered Hexarotor Used in this Research*

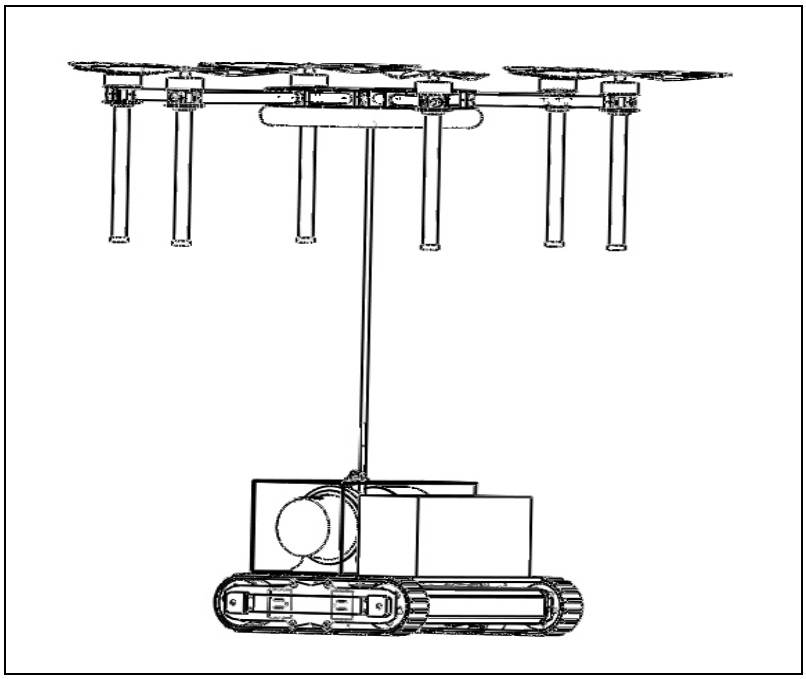

Figure2. *Tethered Hexarotor System*

As the next stage of development we design 48VDC UPS to ensure safety operation and landing during power failure. UAV based UPS systems could be simply categorized in to followings, while avoiding the confusion with existing terminology.

(1) Online prototypes

Denotes prototypes with simultaneous charging and power supplying capability.

(2) Hybrid prototypes

Denotes prototypes that capable of charging when input power is available and discharge the battery when a power failure is detected.

(3) Off-line prototypes

Denotes prototypes equipped with pre-charged batteries and activate the discharge with detected power failure.

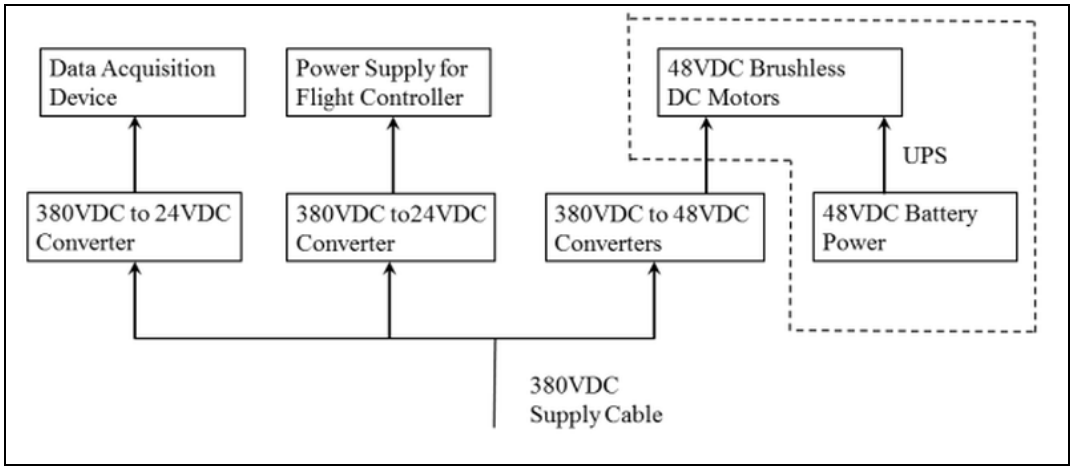

Figure3. *Power Conversion on UAV*

From the technical merit viewpoint Online and hybrid prototypes are higher than off-line prototypes. There are few evidences on developing efforts of hybrid prototypes so far but depending on larger payloads real productions are difficult. Since the motors of our tethered hexarotor requires large currents within a very short period of time as the payload is high and hovering altitudes are low. Hence off-line can be considered as the suitable prototype for our tethered hexarotor.

Few examples on existing researches are such that, in [3] it is explained the DCDC design problem for bidirectional power conversion applicable for tethered UAVs. In [4], [5] and [6] are resent developments on efficient battery power. The most popular battery type in battery powered UAV is still Lipo batteries. As the proposed UPS unit will be working as a backup power supply it is preferred to be of high power and light weighted. In following sections we address the UPS design in details.

TYPICAL UNINTERRUPTIBLE POWER SUPPLY

The following figure 4 illustrates an example of possible hybrid prototype UPS for tethered UAV with medium payload requirements. However the real implementation is doubtful due to long charge limited discharge rate. Extra circuits and wiring adds more complications on existing system. At present charging time of battery is too long comparing to the high current rate requirement at discharge. Designs are still in their primitive stage.

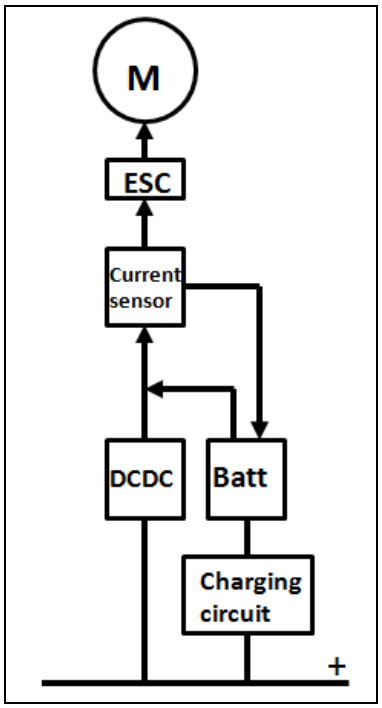

Figure4. *Hybrid UPS for Tethered UAV*

PROPOSED UNINTERRUPTIBLE POWER SUPPLY

The proposed UPS is simple and better as it does not depend on main power supply topology, theoretically does not depend on battery type except the basic features as chemical safety and discharge rate. To make the wiring as simple as possible the best way is to connect the UPS to low voltage bus bar.

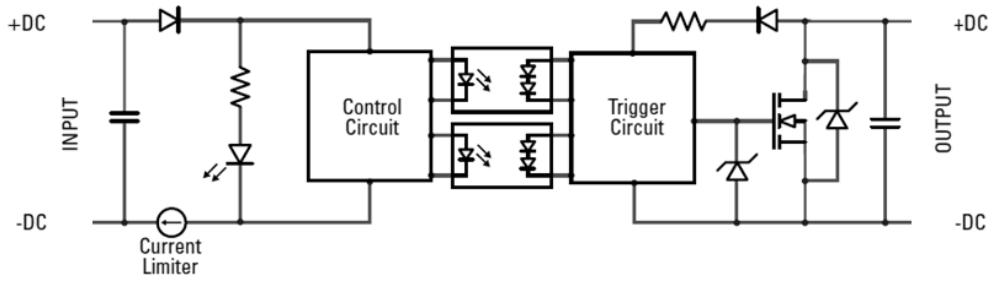

Figure5. *Typical direct controlled DC SSR*

The proposed UPS consists of high speed solid state relay (denoted SSR) and fast switching high current diodes and cascaded pre-charged battery unit. Typical direct controlled DC SSR is illustrated in figure 5. Figure 6 illustrates the proposed high current UPS for our low altitude, heavy payload tethered hexarotor and figure 7 illustrates how to connect the proposed UPS unit to low voltage bus bar of power conversion unit mounted on UAV. Surge absorption circuit (snubber circuit) is applicable since the objective load is inductive, opted in details.

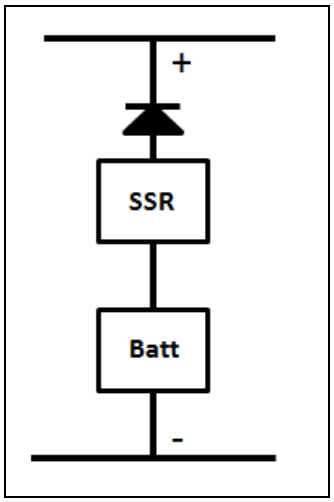

Figure6. *The Proposed UPS*

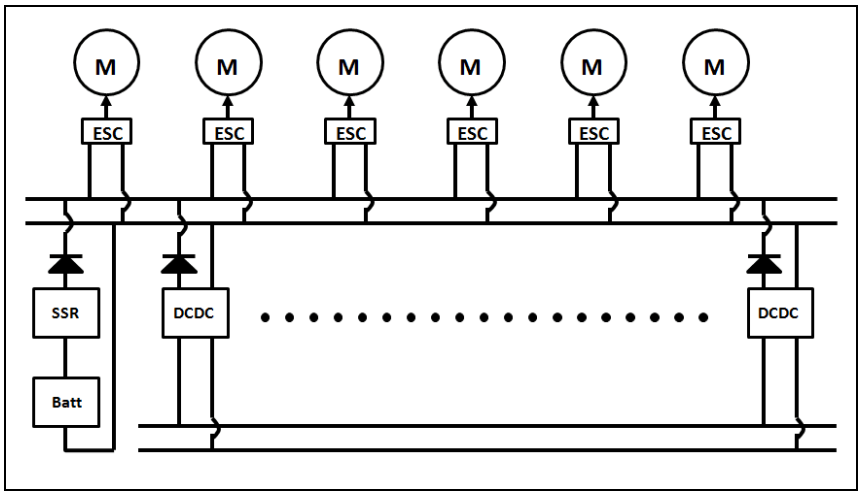

Figure7. *The Proposed UPS with Low Voltage Bus Bar*

Activation of the proposed UPS unit requires additional circuits as illustrates in figure 8. Amplifier circuit depends on SSR specs, i.e. it can be exempted if SSR can be directly controlled with 5VDC activation logic. The activation logic unit consists of 5VDC high speed TTL logic to detect power loss in any ESC power inputs to trigger UPS activation pulse, a latch to hold the logic state till the hexarotor completes the emergency landing and an opto-isolator to avoid operation faults. The activation logic should simultaneously activate the alarms for emergency landing procedures.

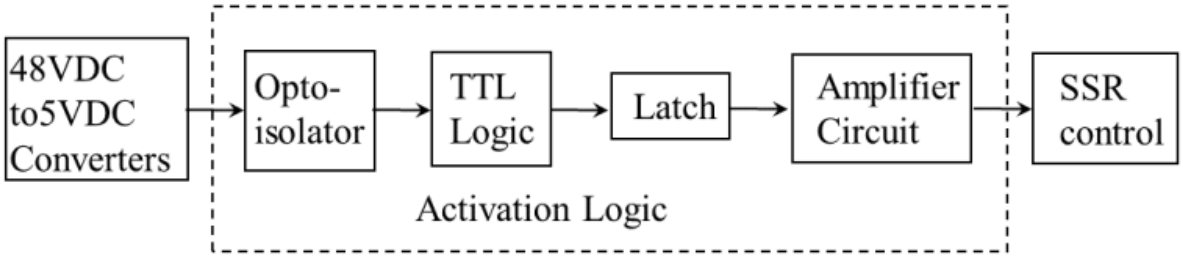

Figure8. *The Control Circuit of UPS*

TECHNICAL REQUIREMENTS FOR VALIDATION

In order to operate accurately the proposed UPS should be able to clear following unit requirements.

(1) Speed of SSR is high

(2) Current ratings of SSR must be high.

(3) Control signal is preferred to be low (microprocessor based switching)

(4) Cascaded high current diode should be fast enough and blocks any possible reverse currents flowing in to the battery unit.

In addition to unit requirements above it is necessary to prevent ESC from restarting before SSR activates the UPS. This is the reason for speed requirement for SSR. In case if ESC enter into resetting mode before SSR, using ESC setting software it is necessary to shut off the low voltage cut-out settings of ESC.

CONCLUSION AND DISCUSSION

In this paper we introduced an off-line uninterruptible power source for heavy payload tethered hexarotors to achieve following targets.

(1) If a sudden power loss occur during flight change to battery power and proceed to safe emergency landing.

(2) Use this UPS for real time power monitoring.

The proposed unit has following technical merits than conventional UPS for UAV applications.

(1) Cost effective.

(2) Reliable.

(3) High speed shifting to battery power.

(4) Easy to implement.

(5) Flexibility to change according to different load requirements. I.e. different payloads, different altitudes.

For the actual product development process, the proposed unit has to be light weighted, compact and be able to clear rigorous safety operation tests before actual implementation on UAV. The product is under a development phase.

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