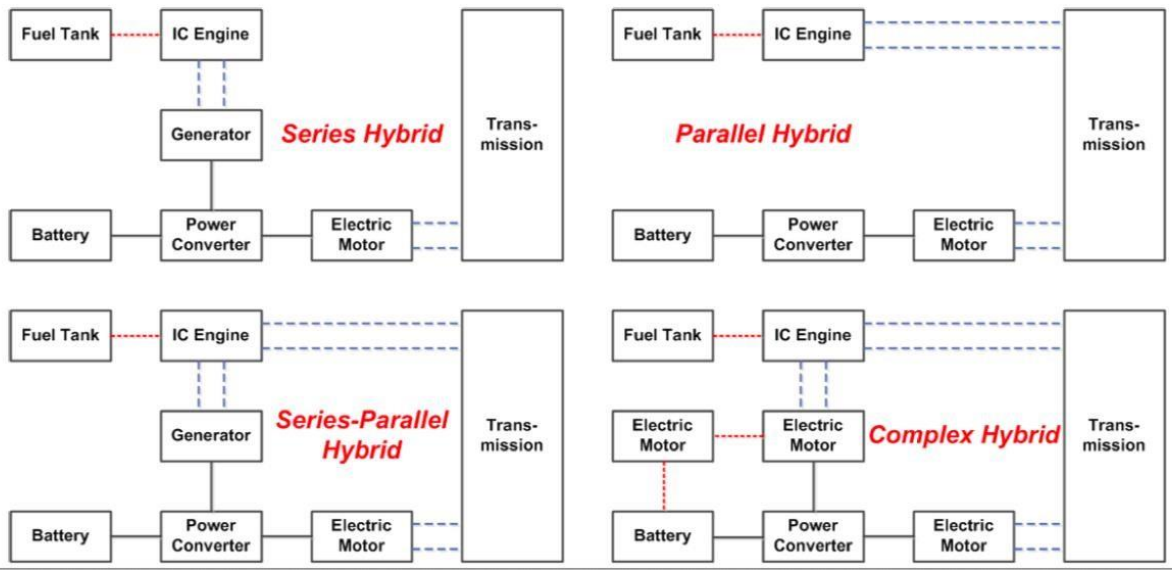
Conceptual Sizing, Performance and Certification Feasibility of a Hybrid Energy General Aviation Aircraft

Description thesis work:

The aim of this particular study is to develop a full general aviation aircraft sizing exercise and also explore conformity challenges with present-day performance and certification requirements (as per EASA CS.LSA) relative to general aviation aircraft.

There has been a steady flurry of announcements on the emergence of Hybrid Energy Aircraft whereby part of the climb, the full cruise and part of the descent are performed by means of battery power-propulsion to be conservatively relieved by conventional means for take-off, approach and landing purposes. Hybrid-electric propulsion systems would present a viable alternative to conventional fuel-burning engines, with the potential to reduce fuel consumption and emissions. Hybrid-electric propulsion systems (HEPS) can indeed take advantage of the synergy between two technologies by utilizing both Internal Combustion Engines (ICEs) and Electric Motors (EMs) together, each operating at their respective optimum conditions. Various projects suggest that aircraft from small to large scale can benefit from HEPS, but the results obtained also indicate that the scaling effects are not directly transferable from one sector to another. In the medium-scale GA sector, the hybrid- electric prototype SOUL aircraft (Hybridization Factor = 60 %) suggests a fuel saving of up to 50 % for short mission profiles (< 1 hour). Increased hybridization of the powerplant leading to even higher fuel savings, but due to the relatively low energy density of batteries today, this increase in efficiency also results in a decrease of the aircraft range. For large-scale aircraft such as commercial airliners, a future fuel saving of up to 10 % has been calculated for HEPS relative to conventional turbofan engines in a current airframe. However, when combined with aerodynamic, materials and structural advancements hybrid-electric propulsion reveals a fuel saving potential of 70 %, together with significant benefits in emissions and noise.

reduction.



Dimensioning design variables were taken into account in Chen Mengxi MS Thesis in 2017 to perform preliminary designs also exploring sizing parameters, series, parallel, series-parallel hybrid, complex hybrid arrangements, performance contours and energy requirements with due regard to future environmental requirements expressed by ACARE. Even if she overly simplified in-

flight battery recharging in her modelizations she demonstrated at least that smaller, regional aircraft would be more likely to offer a distinct advantage over commercial airliners with increasingly heavier batteries cancelling any payload capability for the latter. At least for the moment and a long time to come with too low battery energy densities to make it feasible.
As a matter of fact, foreseeable energy density doubling in the next ten years beyond 500 Wh/kg would still fall short of required power, prompting the need for post-Li-ion technology with batteries (e.g. Li-S) that would be constantly used to power the aircraft. This work will require both a thorough literature review, creative impetus for more extensive modelling and design iterations to benchmark with present designs. Hence a necessary preparadness to contact other industries (e.g. Umicore, Valeo) also engaged in such endeavors. And perhaps seek cooperation with CleanSky (in phase III) through the HASTECS programme part of the EC's horizon 2020.

Zunum's concept (owned by Boeing) is to develop a series of aircraft that can run off of a variety of electrical sources, lowering the cost of air travel significantly and the carbon footprint that goes along with it (the company claims that 40% of all airline pollution comes from regional flights). With initial funding from Boeing and JetBlue Technology Ventures, Zunum plans to start that process with smaller, 10-passenger aircraft and then scale up the airframes as technology improves. Airbus has a similar experimental project with a modified Bae 146. Cooperation between Airbus and Siemens is aiming at propelling large hybrid-electric aircraft of 60-100 passengers, over distances of around 1000 kilometers that could be in the sky by 2030.

Siemens recently unveiled a 50 kg electric motor with a power output of 260 kilowatts, or enough to power a 2-tonne, four-seater electric aircraft when used in conjunction with a small jet engine. This motor has a power to weight ratio of 5kW/kg, or a factor of five higher than existing industrial motors. As a matter of fact Airbus had developed the E-FAN (MTOW 600kg) , whose two engines (32kW/engine) were purely powered by battery (Lithium-ion) with an energy density of 207 Wh/kg, a total available energy of 29kWh for a total battery weight of 167 kg. First flown in 2014 the aircraft had a wingspan on 10,98m by 5.67 length and 1.98 in height but the project was abandoned in 2017. But this should be considered as a stimulus to continue.

Several University projects have been undertaken already in the field of LSA's and the idea is to extend along results gathered from these projects to dedicate an MS Thesis to a preliminary LSA design study with Sonaca considering a version of its Sonaca 200, EASA- certified for a maximum take-off weight (MTOW) of 750kg and cruise speed of 115 knots.

Research Institution	Cambridge University, Flylight	Embry Riddle	Siemens, EADS, Diamond Aircraft	Siemens, EADS, Diamond Aircraft
Project	Hybrid Alatus	Eco Eagle	DA36 E-Star	DA36 E-Star 2
Maiden Flight	2010	2011	2011	2013
Airframe	Alatus-M	Stemme S10	HK 36 Dimona	HK 36 Dimona
MTOW	235 kg	980 kg	770 kg	770 kg
ICE-Type	4-stroke	4-stroke	Wankel	Wankel
ICE	2.8 kW	74.5 kW	30 kW	30 kW
EM	12 kW	29.8 kW	70 kW	65 kW
Battery	LiPo, 40 Ah	LiPo	Unknown	Unknown
Architecture	Parallel	Parallel	Series	Series
Recharge Battery	No	No	Yes	Yes
Take-Off	ICE + EM	ICE	ICE+GE+EM	ICE+GE+EM
Cruise	ICE + EM	EM	ICE+GE+EM	ICE+GE+EM
Climb	ICE + EM	ICE	ICE+GE+EM	ICE+GE+EM
Landing	-	unknown	unknown	unknown

Requirements: Ability to work independently, interest in hybrid engine technology, in light aircraft design and certification, ability to treat vast amounts of different pieces of knowledge and of data, quantitative, analytical and software treatment abilities (e.g. EXCELL, ACCESS, MATLAB).

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