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Short Communication

More Electric Aircraft- for Greener Aviation

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The aviation industry has come under scrutiny for its contribution to greenhouse gas emissions, accounting for approximately 3% of such emissions in Europe alone. To address this issue, the More Electric Aircra - (MEA) concept has emerged as a promising solution to make air travel more sustainable and eco-friendlier.

MEA is based on the idea of replacing traditional hydraulic, pneumatic, and mechanical systems in aircra - with electrical systems. This not only makes the aircraft- lighter but also more fuel- efficient, leading to lower emissions. MEA achieves this through the use of Auto Transformer Rectifier Units (ATRUs), which convert 230 VACS to +270VDC or -270VDC, and power electronic converters that control electrical machines and motors at variable speeds. The traditional centralized power distribution system is also being replaced with a distribution system to reduce line losses and weight.

Electrical loads on commercial aircraft include entertainment units, fans, cabin lighting, kitchen loads, speakers, backup generators etc. Conventional aircraft systems typically use a constant speed drive, to generate 115V/400Hz AC. 115VAC is converted to 28VDC or 14VDC which is used to operate avionics equipment (at levels of 5V, 3V, 12V etc.). Although DC can be extracted directly from the engines by using a DC generator but due to low availability of space near the engines it is complicated to install another generator, also DC conductors that would be used to connect the generator to DC bus are bulky and will add to the weight of aircraft, therefore in constant frequency architecture, AC is converted to DC (by using Transformer Rectifier Unit (TRU)).

In a traditional air-craft electrical system, the generator is connected to a mechanical drive which in turn is connected to the engine, but in modern more electric air-crafts such as A380 and B787, the generator is directly coupled with the engine, which makes mechanical components, such as the mechanical drive, redundant thereby contributing in reducing the weight of the aircraft which will ultimately help in reducing fuel consumption.

Conventionally a jet engine is started through means of pressurized air which is run through the air turbine starter which is in turn connected to the engine shaft by a clutch. It spins the engine compressor until the engine reaches about 4500 revolutions per minute (28.5% of N2) after which engine powers itself by introducing the fuel, about half a gallon per minute, and lights up the mixture. The source of this compressed air can be the External Air Unit or Auxiliary Power Unit (APU). To start APU- batteries, on ground power sources or generators which are driven by the engine, can be used. Traditional functions of APU, in addition to supplying electrical power, are to provide backup hydraulic power in case of failure of the main hydraulic system and to provide compressed air to start the main engine which makes APUs more burdened and comparatively less reliable.

In modern More Electric aircraft, a starter/generator system is used, through which, main engines are started using generators, which are directly coupled with the engine, operated as motors. Electrical energy is provided by the APU, by first converting AC from APU to DC and then DC to AC. This conversion is done in order to get control over variable voltage and variable frequency that is being fed to starter generators.

A starter/generator is a system which allows power to flow in, both directions, between two voltage sources. If one of these sources is an electrical machine and the other is a power electronic converter, acting as a voltage source, then the machine can be operated as both motor and a generator. Conventionally, to start multiple numbers of engines after the first engine starts up, bleed air from the first is diverted towards the second engine through ducts. This method is also used to start engines in-flight, in case of an emergency such as when APU due to lower air density fails to function. In MEA the need for such ducts is eliminated thus reducing the weight of the aircraft. The same power electronic converters, used for DC-AC/AC-DC conversion, can be utilized for other purposes on the aircraft thus eliminating need of extra power converters, therefore, reducing cost and further reducing the weight of the aircraft, which ultimately increases fuel efficiency and also eliminates the need of external equipment such as on-ground engine starter.

With technological advancement, solid-state power electronic devices have become more reliable. As the electrical network in MEA grows, the role of Power electronic converters becomes integral and more important, they now not only have to convert power but also have to control a greater number of electrical machines. Power electronics gives the freedom to operate motors at variable speed, which means motors, employed at numerous locations, can run at their most efficient speed. Increase in mechanical speed results in decreased weight and volume of electrical machines thus, reducing the overall weight of the aircraft and fuel consumption.

The old electrical architecture used to operate at 400Hz which could cause very high inrush current during the start of an induction machine. Through power electronics converter we can replace less efficient and larger induction machines with more efficient and smaller permanent magnet motors thus increasing fuel efficiency. In modern aircraft such as the Boeing 787, for improved efficiency, the output of the cabin pressurization compressors flows through low- pressure air-conditioning packs. The adjustable speed feature of electrical motors will allow further optimization of aeroplane energy usage by not requiring excessive energy from the supplied compressed air and later regulating it down through modulating valves resulting in energy loss. Traditionally centralized power distribution system is used, where power is generated on wings.

With the increasing use of solid-state power controllers and contractors, it is becoming feasible to distribute power near the site of generation. As the distance between generators and loads decrease line losses decrease and so does the rating of the main conductor thus result in a decrease of the overall weight of aircraft.

The first variable frequency system used in A380 simplified constant speed mechanical gearbox. Due to Variable Speed Constant Frequency (VSCF) starter/generator architecture, the constant frequency loads are fed through power electronics converter. In MEA, variable frequency generation will increase reliability by about 50%.

The need to dismantle the drives for maintenance purpose is eliminated, if online condition monitoring is enabled which will reduce risk of reassembling the drives incorrectly making MEA comparatively safer.

Ice on air-craft wings can hamper the aerodynamic lift of the aircraft and may cause it to stall. Apart from existing electrical loads functions like, starting the engine and providing power to passenger environment control, Wing deicing/anti-icing can also be added to the electrical system, by replacing the existing pneumatic system, which will eliminate the need of various parts such as ducts, control valves and pre-coolers which will ultimately reduce the downtime and the weight of the aircraft.

There are two ways to protect wings from ice, which are anti-ice and de-ice. Anti-icing is a preventive measure which avoids the buildup of ice, whereas de-icing removes already built-up ice on wings. In conventional air-craft architecture, pneumatic power is provided to the wing ice protection system, which is extracted from the engines in the form of bleed air, which burdens the engines and hampers their efficiency.

The more electrical architecture includes a blanket heating system (loads in the form of resistors) attached to leading edges and are energized for anti-icing/de-icing functions. Although electrical power generation required per engine is less in traditional aircraft as hydraulics, environmental control and de-icing/anti-icing are not powered by electricity, electrical wing ice protection system, utilize half of the power utilized by the pneumatic system and make a lucrative option because of weight and noise reduction.

Progress is being made in the field of more efficient ice protection systems such as a pulse electrothermal de-icing system, which is expected to save 99% of the energy consumed by the conventional thermal de-icing system.

Elimination of integrated drive generator (IDG)

IDG in the conventional air-craft system is used to obtain constant speed from variable speed of the engine through mechanical means so that frequency can be maintained at a constant level. It has proven to be maintenance-intensive and requires to be replaced frequently. In modern commercial jets need of IDG has been eliminated, as in MEA systems move towards variable frequency. The generator/starter now is directly coupled with the engine and, constant frequency loads are fed via power electronic converters.

Electromechanical (EMA) / Electrohydraulic actuators (EHA)

The hydraulic system in a conventional architecture consists of namely three systems Green, Yellow and Blue. Green and Yellow hydraulic system burden the engine by drawing power from the engine-driven pumps whereas the Blue hydraulic system is run by electric power. The hydraulic system is used for primary and secondary surface controls such as braking, landing gears, doors, reverse thrust engine control etc. Major drawbacks of such a system are less efficiency and bulky infrastructure. It is inefficient in detecting leaks and also conjures the risk of fire due to leakage of flammable hydraulic liquid. In MEA, the EHA system is utilized which is a distributed hydraulic system and operates individual small hydraulic pumps,[18] which can be isolated in case of failure or emergency.

EHA is a self-contained unit which eliminates the need for fluid tank, piping and external hydraulic source. EHA contains various parts such as a hydraulic cylinder, a power module and a mounting interface with the device being driven. The hydraulic oil is sent to the cylinder from power module according to required position of the connected device (there are two ways of implementing EHA which are by, using an electric motor with variable speed and fixed displacement hydraulic pump or using a motor with fixed speed and variable displacement hydraulic pump)

This more electrical architecture is comparatively more beneficial as localized pumps draw power only when there is a need, such as during aircraft making a bank. Whereas hydraulic system acts as continuous load, affecting the efficiency of the engine. EMA, moves the actuator through roller-screw which is operated by a permanent magnet synchronous motor and, is more efficient because it can run the hydraulic pump in reverse as well, as it uses gearbox for linear motion in place of hydraulic power. EMA forms a decentralized system as compared to a centralized system involving EHA and is less maintenance intensive as compared to EHA. EMA also eliminates the of the need for hydraulic fluid, which adds to the weight of aircraft and, involves lesser initial cost Thus EHA or EMA system reduces weight and improves the fuel efficiency of the aircraft.

A fault anticipating software can be developed to detect faults early on in EMA, thus making it a safer option for primary flight controls as well.

With help of an aircraft performance model, replacing the hydraulic system with more electric technologies resulted in minimum, 0.1%, 0.1% and 0.25% reduction in Operating Empty Weight (which is the standard basic weight of an aircraft), of Airbus A330-200, A380-100 and A340-500 respectively.

The bleed-air architecture of conventional aircraft results in less efficiency of the engines. Non- thrust power of conventional air-craft is approximately 1.74MW, which is 74% higher than that of MEA .In the no-bleed system of the aircraft, instead of tapping bleed air from the engine for the environmental control system, compressors running on electrical energy is used to regulate temperature and pressure so that engine can use saved bleed air for more thrust production and result into lower consumption of fuel and extended range of operation. As bleed air from the engine is not being utilized for non-thrust purposes, pneumatic systems are eliminated thus reducing the weight of the aircraft and toxic hazards, for passenger, such as the risk of oil leakage, which can enter the cabin through air ducts in form of smoke, is eliminated. As such there is no sensor installed, in the current system of conventional air-craft, to detect this oil leak apart from natural smell sense of pilots. By installing no-bleed architecture in MEA it has been observed that up to 35% less power is drawn as compared to conventional air-craft.

Drawing less power means less fuel consumption and also the elimination of ducts contributes in reducing the weight of the aircraft. This architecture can lead to up to 2% saving in fuel consumption, while on cruise mode. By utilizing electric compressors and eliminating the need of bleed air for cabin pressurization and temperature control, we can obtain more efficient secondary power transfer and maintenance costs can be reduced (because this system uses lesser number of parts) Efficient secondary power transfer could save up to 3% fuel as compared to a conventional air-craft system. Air-craft energy can be thoroughly utilized by using motors, employed in compressors and fans to circulate air, which have controllable speed characteristics.

By utilizing aircraft performance model, it was observed that, substituting bleed air system and hydraulic system with more electric technologies, can result in fuel saving, up to 2.6%, 3.5% and 2.75% in A330-200, A380-100 and A340-500 air-crafts respectively.

An aircraft is pushed out of the terminal using a tug vehicle, after which it uses engine thrust to taxi till runway. At major hub airports, taxiing can consume a large amount of time due to traffic and long distances to reach the runway, for example, flights spend an average of 40 minutes in taxiing at JFK. Meanwhile, engines produce very less thrust and are idle for most of the time, burning up a significant amount of fuel. Till the time an aircraft is on the ground, it can consume up to 3% of the total amount of fuel to be used in flight. MEA architecture proposes using motors embedded in landing gears to be used for taxiing, so that engines can be started shortly before takeoff so that they run for a shorter time and consume less fuel. Aircraft employing this architecture can have a faster push-back saving time and cost for the carrier.

After landing too, motors can drive the aircraft to gates meanwhile shutting off the engines and saving fuel and emissions. The cost and emissions (unless electric) of tug-vehicle can also be eliminated.

Electric taxi system requires conditioned power from the APU to be fed to traction motors using power electronic converters. If alternate sources of energy such as fuel cells are used, taxiing has the potential to become completely emission-free.

One of the biggest advantages of MEA is its potential to reduce carbon emissions. A comparative study of MEA and conventional aircraft- shows that MEA is more efficient, with a higher voltage level reducing the weight of conductors, and electronic systems processing power before being distributed to various loads. The first variable frequency system was used in the Airbus A380 model, which reduced fuel consumption and simplified constant speed mechanical gearbox. Therefore, it is safe to say that MEA has the potential to reduce fuel consumption, greenhouse gas emissions, maintenance costs, and increase reliability.

MEA also eliminates the Integrated Drive Generator (IDG) and No-Bleed air system, which reduces the risk of toxic hazards for passengers and improves safety. Moreover, MEA reduces weight and fuel consumption by replacing hydraulic and pneumatic systems with electrical systems for various functions such as wing ice protection, actuators, and environmental control.

The adoption of MEA architecture by aircraft- manufacturers is crucial for reducing carbon emissions and improving efficiency. As the aviation industry continues to grow, it is necessary to prioritize sustainability and eco-friendliness to ensure a better future for the planet. MEA is a step in the right direction and must be encouraged and supported by all stakeholders in the aviation industry.

In conclusion, the More Electric Aircraft- (MEA) concept is an innovative and sustainable solution that can help the aviation industry reduce its carbon footprint and improve efficiency. The use of electrical systems instead of traditional hydraulic, pneumatic, and mechanical systems in aircraft- leads to lighter and more fuel-efficient planes, resulting in lower emissions. The benefits of MEA are many, and the adoption of this architecture by aircraft-manufacturers can pave the way for a greener and more sustainable future for air travel.